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THE EFFECT OF USMC ENLISTED AVIATION MAINTENANCE QUALIFICATIONS ON AVIATION READINESS

by

Zachary D. Germershausen
Scott A. Steele

December 2015

Thesis Advisor: Simona Tick
Associate Advisor: Mark J. Eitelberg

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THE EFFECT OF USMC ENLISTED AVIATION MAINTENANCE QUALIFICATIONS ON AVIATION READINESS

Zachary D. Germershausen
Captain, United States Marine Corps
B.B.A., University of North Florida, 2010

Scott A. Steele
Captain, United States Marine Corps
B.S., United States Naval Academy, 2010

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Approved by: Simona Tick
Thesis Advisor

Mark J. Eitelberg
Associate Advisor

Chad Seagren, Academic Associate
Graduate School of Business and Public Policy

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LIST OF ACRONYMS AND ABBREVIATIONS

AMSRR	Aviation Management Supply and Readiness System
ASM	Advanced Skills Management
CDI	Collateral Duty Inspector
CDQAR	Collateral Duty Quality Assurance Representative
DECKPLATE	Decision Knowledge Programming for Logistics Analysis and Technical Evaluation
FMC	Full Mission Capable
HMH	Marine Heavy Helicopter Squadron
HMLA	Marine Light Attack Helicopter Squadron
MACCRAT	Marine Aviation Commander’s Current Readiness Assessment Tool
MC	Mission Capable
MCTFS	Marine Corps Total Force System
MOS	Military Occupational Specialty
NAMP	Naval Aviation Maintenance Program
NMC	Non Mission Capable
RBA	Ready Basic Aircraft
QAR	Quality Assurance Representative
TFDW	Total Force Data Warehouse
VMM	Marine Medium Tilt-rotor Squadron

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I. INTRODUCTION

> My responsibility can be distilled into one word: READINESS. I personally, along with my team in HQMC Aviation, have no other purpose than to ensure, and be held accountable for, the Corps' aviation readiness now and in our future. To deliver current and future readiness I will focus on flying, training, innovation, standardization, and culture, along with right-sizing and resourcing Marine Aviation forces to meet our operational requirements.
>
> —LtGen Jon "Dog" Davis,
> Deputy Commandant Aviation
> (Headquarters Marine Corps, 2014, p. 4)

A. OVERVIEW

One cannot deny that success in any organization depends largely on its personnel. The U.S. Marine Corps (USMC) is no exception, always seeking the optimum quantity and quality of personnel. A significant proportion, 21% of enlisted Marines, serve in aviation-related MOSs, as shown in Table 1 (USMC Concepts & Programs, 2015). Part of this work force is directly responsible for the upkeep of highly technical aircraft, which are often in high demand.

Table 1. Number of USMC Enlisted Personnel by Aviation MOS, 2015

	2015	
USMC Enlisted Personnel	**Aviation MOS's**	
	60	5,336
	61	6,949
	62	4,199
	63	4,806
	64	3,170
	65	2,767
	66	2,060
	68	464
	70	2,435
	72	2,066
	73	241
	Total Aviation Enlisted	34,493
	Total USMC Enlisted	167,138
	Proportion Aviation	**20.6%**

Adapted from: "2015 USMC Almanac" U.S. Marine Corps. (2015, Mar 11). *Occupational Field Distribution*. (United States Marine Corps) Retrieved Jun 17, 2015, from U.S. Marine Corps Concepts & Programs: https://marinecorpsconceptsandprograms.com/almanacs/active-duty-enlisted/occupational-field-distribution

Readiness is top priority for the current Deputy Commandant of Marine Aviation (DCA), Lieutenant General Jim Davis, as emphasized in the 2015 Marine Aviation Plan (Headquarters Marine Corps, 2014). Aircraft readiness is the primary metric used for flying squadrons and the central focus of the present study. This thesis seeks to take aircraft readiness, which is an easily-quantifiable metric, and compare it with relevant personnel information across multiple squadrons and time-series. Although many factors influence aircraft readiness, trained and qualified Marine mechanics may impact it most significantly.

B. PROBLEM AND HYPOTHESIS

It is clear from the 2015 Marine Aviation Plan that aviation must consider ways to increase its readiness in meeting the modern-day demands of Marine aviation (Headquarters Marine Corps, 2014). Unlike a for-profit business, Marine aviation can measure its revenues in the form of successful operations and readiness metrics. These metrics are the result of quality personnel, equipment, and training. Regarding personnel, the Marine reenlistment process only indirectly includes technical qualifications. As the Enlisted Retention and Career Development Manual states, “[Commanding Officers’] recommendation should take into consideration Marine’s performance and conduct as it relates to rank, age, experience and maturity level” (Headquarters Marine Corps, 2004, pp. 4–5).

Although rank is correlated to some degree with levels of aviation maintenance qualifications, many Marine maintainers are unqualified or under-qualified with respect to their rank. The problem created by this system is that a mechanic could theoretically possess an aviation mechanic Military Occupational Specialty (MOS), but have no authority to fix aircraft or increase readiness. Assuming that Marine aviation measures its outcomes in terms of successful operations and readiness, proper value should be assigned to qualifications. No mathematical basis currently exists to justify the impact of qualifications on readiness and no attempt to quantify the worth of qualifications has been undertaken. Human capital, resulting from training, is not formally valued as a maintainer, and no monetary value has been assigned to qualifications in providing a basis for proper retention incentives. In a country that places high demand on its Marine Corps, and in a world that is growing increasingly technical, there is cause for concern of improper staffing and retention processes.

This study aims to examine three technical qualifications: Collateral Duty Inspector (CDI), Collateral Duty Quality Assurance Representative (CDQAR), and Quality Assurance Representative (QAR), regarded as the top technical experts within an aviation squadron. These qualifications are required for flightline, avionics, and airframe mechanics MOSs. Only rotary wing squadron types—which includes Marine Heavy Helicopter (HMH), Light Attack (HMLA), and Tiltrotor (VMM) squadrons—are used in this study. These three types of squadrons utilize the same qualification structures, enabling this study to compare qualifications across squadron types.

The researchers hypothesize in this thesis that aircraft readiness, a maintenance department's strategic goal, relies more heavily on qualifications than on rank. This thesis does not focus on first-term qualifications, since it is assumed that most first-termers will leave after one enlistment and their level of technical experience is assumed to be low when compared with personnel in subsequent terms. Therefore, the study focuses on Marines aviation mechanics in their second term, recognizing that they have more qualifications and experience.

The main research question of this thesis is to test empirically the hypothesis that qualifications have a strong, positive effect on aircraft readiness, such as Ready Basic Aircraft (RBA) and Mission Capable (MC) aircraft percentages. Further, the thesis investigates whether more advanced qualifications have a stronger positive effect on readiness. The analysis in this thesis assumes that rank is not a significant indicator of qualification, whereas other performance and experience variables are.

C. PURPOSE

The present study uses multivariate statistical analysis to identify the relation between personnel aviation qualifications and aircraft readiness. This study seeks to provide a mathematical basis or foundation for enlisted aviation manpower staffing requirements and qualification-specific incentive policies. The process used in this study can be applied to other highly-technical job fields within aviation, the Marine Corps, and the Department of Defense (DOD) more generally.

D. RESEARCH QUESTIONS

1. Primary Research Question

- What is the effect of USMC enlisted aviation maintenance qualifications on squadron aviation readiness?

2. Secondary Research Questions

- Do other factors—such as pay grade/rate, marital status, family size, race, duty station, and test scores—affect enlisted qualifications in aviation maintenance?
- Does each successive reenlistment affect qualifications?
- What type of qualification structure should a squadron have when given an expected level of readiness?

E. METHODS

To analyze the population, qualifications, and readiness across aviation units, descriptive statistics are formulated using a cross-sectional data set resulting from the merge of a personnel database, an aviation maintenance qualification database, and an aircraft readiness database. A multivariate linear regression model is then applied to the data set to determine which human factors affect qualifications. In addition, a second data set is created from aircraft readiness and manpower data over time, based on information provided by Naval Aviation Enterprise (NAE). Using this second data set, researchers employ descriptive statistics and multivariate linear regressions to analyze the effect of qualifications on aircraft readiness.

Monte Carlo simulations are used to show the range of the effect of qualifications on readiness and to suggest proper qualification composites, given a desired aircraft readiness level for a typical squadron type. Descriptive statistics and multivariate regression utilize Microsoft Excel and Stata software. The Monte Carlo simulation is conducted using Crystal Ball software.

F. SCOPE AND LIMITATIONS

The quantitative analyses conducted for this study are somewhat limited due to data availability. For example, a number of factors that might contribute to readiness are not captured by the available data set. In addition, the Monte Carlo simulation results, which rely on the multivariate analysis results, are constrained by the possible qualification and personnel staffing scenarios used in the simulation. Researchers explore these limitations and the presumed effects of other factors on readiness in qualitative sections of the thesis.

This study is also limited by providing information related only to readiness of the aviation fleet operating forces. The results do not take into account USMC manpower requirements outside of aviation. The scope of the study is narrow by design, seeking to provide USMC policy makers with insight into aircraft readiness and maintenance qualifications.

G. ORGANIZATION OF STUDY

This thesis is organized into six chapters. Chapter II provides background information on matters related to USMC aviation, aircraft readiness, qualifications of enlisted aircraft maintainers, and retention challenges. Chapter III presents examples and synthesizes previous research that may apply to the present study through a literature review. Chapter IV describes the data used as inputs to the models and the preliminary relevant characteristics of the data collected. Chapter V focuses on the multivariate analysis and simulation, which quantifies the effect of qualifications and human factors on aircraft readiness. Chapter VI summarizes the study, draws conclusions, and recommends approaches for future manpower policies.

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II. BACKGROUND

A. USMC AVIATION MAINTENANCE

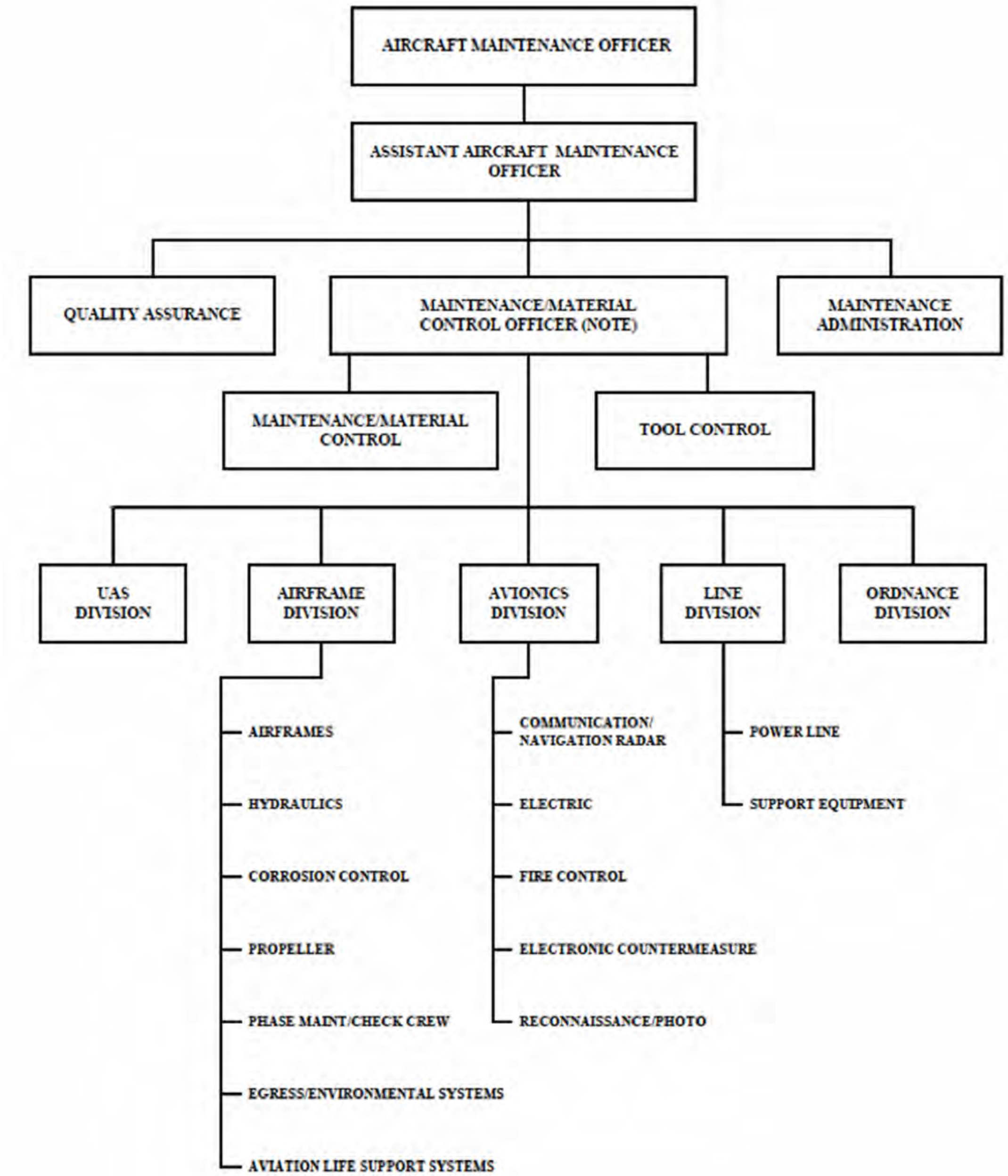
1. Naval Aviation Maintenance Program

The current Naval Aviation Maintenance Program (NAMP) is a document produced in 2013 by the Chief of Naval Operations (CNO), which oversees all levels of aviation maintenance in the Navy and Marine Corps. The NAMP has been a working document since its inception and is periodically updated to meet the dynamic environment of aviation. The goal of the NAMP is to standardize maintenance policies, procedures, and responsibilities within the realm of naval aviation. The NAMP is the paramount document in the practice of aviation maintenance. It serves as the basic guideline for each maintenance department to follow to achieve the safest conditions possible in a very volatile environment. The analysis conducted in this thesis will take into account extensively the NAMP policies, procedures, and responsibilities. Therefore, the next section presents in detail the essential elements of the NAMP, all considered in the analytical sections of the thesis.

2. Squadron Composition

Figure 1 presents an outline of the maintenance department, as directed by the NAMP. The NAMP also goes into fine detail on the responsibilities and expectations of each entity presented in Figure 1. The Maintenance department is led by the Aircraft Maintenance Officer (AMO), who is directly responsible to the squadron’s commanding officer for all things pertaining to maintenance. The AMO is assisted by the Assistant Aircraft Maintenance Officer (AAMO). Three work centers facilitate maintenance: Quality Assurance (QA), Maintenance Control, and Maintenance Administration (MA) (Commander, Naval Air Forces, 2012).

Figure 1. O-level Maintenance Department Line and Staff Relationship (Marine Corps)



Source: Commander, Naval Air Forces. (2012, May. 15). Naval Aviation Maintenance Program (NAMP) (4790.2B). San Diego, CA: Author

The QA division is directly responsible to the AMO for ensuring the regulations outlined in the NAMP are being followed. The QA division is responsible for inspecting the squadron for adherence to the appropriate regulations. While every Marine in a squadron is responsible for ensuring that safety is the priority, QA serves as the safety authority for the squadron. According to the NAMP: "The QA Division is comprised of a small group of highly skilled personnel and is manned differently depending upon the maintenance level assigned. These permanently assigned personnel under the QA Officer are responsible for conducting and managing the maintenance departments QA effort" (Commander, Naval Air Forces, 2012, 7.2.1.1). QA initiates and oversees the progression of maintainer qualifications. Utilizing Advanced Skills Management (ASM), QA personnel are able to track and review maintainer's progression toward qualifications and ensure that the required syllabus has been completed prior to endorsement and ultimate AMO signoff.

The Maintenance Control division drives the priorities of the production work centers. As with QA, Maintenance Control is comprised of vastly experienced Marines from each production work center. The main effort of Maintenance Control and production work centers is to ensure that the daily flight schedule is met. The flight schedule is generated by a squadrons' Operations department (not a production work center) and delivered to Maintenance Control the previous day. Maintenance Control then ensures that aircraft assigned to the daily flight schedule have the appropriate metric of readiness, and are inspected prior to flight. (Metrics of readiness are covered later in this chapter, in Section B.) Coordination of individual production divisions' efforts is fundamental to assigning aircraft to the flight schedule. As shown in Figure 1, the production work centers consist of Airframes, Line, Avionics, Ordnance, and Unmanned Air systems. Each division is manned by Marines who have the associated MOS. These Marines follow established syllabi to achieve qualification levels. (Qualifications are covered later in this chapter, in section C.) The relationship between QA and Maintenance Control is a compilation of checks and balances. Although aircraft maintenance may appear unambiguous with all of the directives and technical publications, many instances are subject to interpretation. For this reason, "Direct liaison between QA and production divisions is a necessity and must be energetically exercised" (Commander, Naval Air Forces, 2012, 7.1.6.3).

The MA division continues the necessary level of accountability required of a squadron by the NAMP. Where QA is the controller of technical publications, MA is the sole custodian of non-technical publications. MA's priority is to "Establish and control a central maintenance reporting and record keeping system for all administrative reports and correspondence, if not already centrally located in the command's Administration Department, including a tickler file to assure timely submission of recurring reports" (Commander, Naval Air Forces, 2012, 3.5.4.5). All maintenance-related correspondence pertaining to a squadron is aggregated and disseminated through appropriate channels via the MA work center. MA is crucial in the reporting of accurate readiness metrics.

3. USMC Rotary Wing Aircraft

The analysis conducted in this thesis focuses on the rotary wing platforms of USMC. Three types of squadrons are examined: the Marine Light Attack Helicopter Squadron (HMLA), the Marine Medium Tilt Rotor Squadron (VMM), and the Marine Heavy Helicopter Squadron (HMH).

The HMLA's primary mission is to "support the MAGTF commander by providing offensive air support, utility support, armed escort and airborne supporting arms coordination, day or night under all weather conditions during expeditionary, joint or combined operations. [Further,] conduct intelligence, surveillance and reconnaissance missions and MAGTF electronic warfare missions" (Headquarters Marine Corps, 2014, 2.6.2). The HMLA included in this study is comprised of the AH-1W/AH-1Z Cobra and the UH-1N/UH-IY Huey, as shown in Figure 2. The time range of the data collected falls directly during the time that the USMC was undergoing a transition to upgraded platforms. The traditional squadron includes the AH-1W and the UH-1N. UH-1Y initial operational capability was achieved in 2008, transforming some squadrons to AH-1W and UH-1Y, while other HMLAs remained status quo (Headquarters Marine Corps, 2014). The following installments of upgrades transitioned the AH-1W to the AH-1Z. There have been three compositions of HMLAs from 2008 to present: the traditional AH-

1W/UH-1N, the partially upgraded AH-1W/ UH-1Y, and the fully upgraded AH-1Z/UH-1Y. All active squadrons have successfully transitioned to the UH-1Y by September 2014, and the predicted transition completion for USMC reserve HMLAs is 2017. The 1st, 2nd and 3rd Marine Air Wings will be AH-1Z transition-complete in 2019. An HMLA has a Primary Mission Aircraft Authorization (PMAA) of 27 Aircraft, 18 AH-1W and 12 UH-1Y or 15 AH-1Z and 12 UH-1Y. The PMAA was recently degraded to 13 AH-1W and 13 AH-1Z due to "shallow aircraft fielding ramp and fielding decisions" (Headquarters Marine Corp, 2014, 1.3).

Figure 2. UH-1N Iroquois Huey (top left), UH-1Y Venom Huey (bottom left), AH-1W Super Cobra (top right), AH-1Z Viper Cobra (bottom right)

Source: Headquarters Marine Corps. (2014, Sep). Marine aviation plan: 2015. Washington, DC: Author

The mission of the HMH is "Support the MAGTF commander by providing assault support transport of heavy equipment, combat troops, and supplies, day or night, under all weather conditions during expeditionary, joint or combined operations.

[Further,] conduct intelligence, surveillance and reconnaissance missions and MAGTF electronic warfare missions” (Headquarters Marine Corps, 2014, 2.6.2). The HMH helicopter is the CH-53E, shown in Figure 3. During the time frame considered for this thesis, 2012 to 2015, there were no transitions to upgrades for the CH-53E; however, the HMH squadrons did suffer from CH-53E inventory shortages due nonexistent replacement production and Depot Level maintenance requirements (Headquarters Marine Corps, 2014, 2.6.4). The PMAA for a HMH is 16 aircraft; yet, due to issues with inventory, PMAA has been shifted to 13 aircraft.

Figure 3. CH-53E Super Stallion

Source: Headquarters Marine Corps. (2014, Sep). Marine aviation plan: 2015. Washington, DC: Author

The VMM’s primary mission is to “Support the MAGTF commander by providing assault support transport of combat troops, supplies and equipment, day or night under all weather conditions during expeditionary, joint or combined operations” (Headquarters Marine Corps, 2014, 2.6.2). During the time horizon considered for the analysis conducted in this thesis, the introduction of the MV-22B, shown in Figure 4, was just taking hold. The deployment of the MV-22B and the VMM began in 2007 and has been growing in size ever since. As of September 2014, the creation and staffing of the VMM squadrons was 65% complete. The predicted completion of active VMM squadron standup is 2019. The PMAA for a VMM squadron is 12 MV-22B.

Figure 4. MV-22 Osprey

Source: Headquarters Marine Corps. (2014, Sep). Marine aviation plan: 2015. Washington, DC: Author

B. AIRCRAFT READINESS

1. Aircraft Readiness Defined

Marine Corps squadrons have several metrics for readiness. The basis for reporting readiness depends on how many operating aircraft a particular squadron has in Material Condition Reporting Status (MCRS). According to the NAMP: “An aircraft that moves to a rework facility for purposes of rework will leave operating status and remain in the reporting custody of the operating unit unless FS status is requested and granted by OPNAV” (Commander, Naval Air Forces, 2012, Appendix 20). This means that the aircraft will be listed on the daily Aviation Maintenance Supply Readiness Reporting (AMSRR) report, but will not be included in the squadron’s readiness rates.

Traditional measures of readiness are Full Mission Capable (FMC), Partial Mission Capable (PMC), and Non Mission Capable (NMC). The NAMP states, “FMC captures whether the material condition of an aircraft that can perform all of its missions.” (Commander, Naval Air Forces, 2012, Appendix 20). PMC is defined as the “material condition of an aircraft that can perform at least one but not all of its missions” (Commander, Naval Air Forces, 2012, Appendix 20). The total combination of aircraft that are FMC and PMC is considered the operating squadron’s Mission Capable (MC) aircraft. MC aircraft are a priority for fleet units in the Navy and Marine Corps. As the NAMP states: “The CNO established 73 percent MC and 56 percent FMC as the overall NAE aircraft material readiness goal” (Commander, Naval Air Forces, 2012, Appendix 20, 17.2.1). When an aircraft is determined as NMC, its “material condition is not capable of performing any of its missions” (Commander, Naval Air Forces, 2012, 17.2.1). Both PMC and NMC can be subdivided into two categories, based on the driving factor of degradation. The two factors are either maintenance or supply. A plane that is either Partial Mission Capable Supply or Non-Mission Capable Supply is in the degraded status because of a supply shortfall. Partial Mission Capable Maintenance and Non-Mission Capable Maintenance refer to aircraft experiencing inoperability due to existing maintenance requirements only.

However, traditional metrics for readiness described above do not capture the true number of Ready Basic Aircraft (RBA) that are Ready For Tasking (RFT). The NAMP states, “RFT calculations result from combining RBA and specific configurations of mission systems” (Headquarters Marine Corps, 2009, 1–2). Ready basic aircraft have two requirements. First of all, the plane must not require a Functional Check Flight (FCF). FCF is normally needed after any major maintenance action. The FCF is “required to determine whether the airframe, power plant, accessories, and equipment are functioning per predetermined standards while subjected to the intended operating environment” (Commander, Naval Air Forces, 2012, 5.1.1.4). Second, for an aircraft to be considered RBA, there can be no maintenance or supply requirements that have an “L” Equipment Operational Capability (EOC) code. The EOC code for each platform is defined in the respective Mission Essential Subsystems Matrices (MESM). An “L” EOC code is registered whenever “the aircraft is not capable of day or night VMC/IMC field of flight operations with necessary communication, IFF, navigation, flight and safety systems required by applicable NATOPS and FAA regulations” (Headquarters Marine Corps, 2009, pp. 1–3). The added metrics of RBA and RFT, combined with the traditional FMC, PMC, and NMC rates, give senior leadership a precise measurement of the on-hand aircraft available for mission assignment. As with the PMAA, the Marine Corps Aviation Plan also dictates the standard for RBA aircraft amount per TMS. The required number of RBA is eight, seven, and sixteen for the HMH, VMM, and HMLA, respectively. Unlike the PMAA, however, the required number of RBA aircraft is not degraded to account for logistical and fielding constraints. This means that the same amount of RBA is still required from a TMS, regardless of how degraded their inventory is.

2. Reporting Aircraft Readiness

As discussed above, the USMC squadrons have multiple metrics for measuring readiness. The Marine Corp Readiness Reporting Standard Operating Procedures states, "accurate and timely [squadron] readiness reports are essential for Joint Readiness reporting" (Headquarters Marine Corps, 2010, p. 1–1). Commanders must know the capabilities and limitations of their squadrons and squadrons' assets to execute assigned missions. The scope of aircraft readiness reporting is captured by two different reporting processes.

The first reporting system is the AMSRR. The AMSRR is the web-based reporting system that requires all units operating under the NAE to report their daily NMC, PMC, FMC, as well as RBA measurements. It offers a snapshot in time that is communicated up to the CNO. It highlights each squadron's individual aircraft and the associated maintenance actions, along with the parts for which each aircraft is waiting in the supply system. The maintenance actions are updated daily by the individual squadron, while the timeline of the part delivery is updated daily by the entities within the supply system.

The second reporting system is Naval Aviation Logistics Command Management Information System (NALCOMIS). According to a Space and Naval Warfare Systems Center (SSC) Atlantic web site:

> Naval Aviation Logistics Command Management Information System (NALCOMIS) is an automated information system that provides aviation maintenance and material management personnel with timely, accurate and complete information on which to base daily decisions. It is a single,

> integrated, real-time automated system that supports workers, supervisors and managers. NALCOMIS features an automated source data entry device for simplifying and improving data collection, while also furnishing a means to satisfy the Naval Aviation Maintenance Program (NAMP) requirements. ("About NALCOMIS," n.d.).

Unlike AMSRR, NALCOMIS is a working database that controls the entire maintenance and supply activity within a squadron at any given time. Each aircraft is searchable within the squadron, and it shows every discrepancy that is currently afflicting it. Each discrepancy tracks what individual has worked on it, along with what toolboxes were used while in work. Every serialized part is listed in NALCOMIS with its associated aircraft. A coding feature, much like the EOC codes mentioned before, tracks the status of each aircraft. The total hours of each discrepancy are logged and distinguished between hours waiting for a supply shortfall or hours taken to complete a maintenance action. Monthly, the total aircraft and maintenance/supply hours are sent to a historical database named DECKPLATE. A description of DECKPLATE is presented later in the chapter.

C. QUALIFICATIONS OF ENLISTED AIRCRAFT MAINTAINERS

Personnel qualifications are built into aviation maintenance on many levels. When Marines graduate from their respective designation school and earn their maintenance MOS, the only qualification they possess is the ability to work on a specific type of aircraft and a specific type of system. On-the-job (OJT) training is the essence of maintainer development. Proficiency must be achieved and demonstrated for a Marine to advance in qualifications. Each MOS has an established, standardized curriculum mandating levels of expertise be met to achieve qualifications. The qualifications are specified in the Aircraft Maintenance Training and Readiness Program (AMTRP) manual. According to a report on the aircraft maintenance training and readiness program, "The AMTRP provides the structure, policy, and readiness metrics required to standardize maintenance training and identifies required resources to aid Marine aircraft maintenance departments in training, developing and sustaining aircraft MOS-specific skills (Headquarters Marine Corps, 2009, 1.1.4).

1. Categories of Qualifications Held

As aviation maintenance Marines progress through their careers, qualifications serve as milestones of proficiency and seniority. The first major qualification for a maintainer is Collateral Duty Inspector (CDI). A CDI is the staple in the maintenance department. As the NAMP states: “CDI candidates are required to demonstrate their knowledge and ability on the particular equipment by successfully passing a written examination administered by QA. In addition to the written examination, an oral or practical examination may be used” (Commander, Naval Air Forces, 2012, 7.4.5.2). When Marines achieve the title of CDI, they have accumulated significant skill and technical knowledge to work on their MOS-specific systems without supervision. They also have the ability to supervise non-CDI and Collateral Duty Quality Assurance Representative (CDQAR) Marines conducting OJT (Commander, Naval Air Forces, 2012, 7.4.5.1). A CDIs signature on a Maintenance Action Form (MAF) serves as a function of Quality Assurance (QA) and indicates that the maintenance conducted was in accordance with all technical publications and was inspected accordingly.

The CDQAR is the next pivotal milestone in an aviation maintenance Marine’s career. A CDQAR is a seasoned maintainer and has significantly more experience and training logged than a CDI. A CDQAR is predominantly responsible for a work center’s QA function on Maintenance Requirements Cards (MRC). The NAMP observes: “MRCs are provided for certain maintenance tasks that, if improperly performed, could cause equipment failure or jeopardize the safety of personnel” (Commander, Naval Air Forces, 2012, 7.1.7.6). In a work center, the CDQAR is the epitome of maintenance leadership and is entrusted with a great deal of responsibility. Whenever an aircraft undergoes maintenance that requires an FCF, the CDQAR is accountable for inspections during the maintenance action, and the final inspection before the test flight is conducted. Each CDQAR is directly responsible to the squadron’s Maintenance Officer (MO), which is a direct reflection of authority. If the MO determines that a particular MAF requires an additional level of inspection, the MO can mandate that a CDQAR is required to conduct inspections prior to signing off the maintenance action.

A Quality Assurance Representative (QAR) serves the same purpose of the CDQAR, however, QARs are assigned to the QA work center instead of their MOS-designated work center. QARs tend to have well-rounded training, with a proven record of superior maintenance practices. The NAMP requires that a QAR,

> Be senior in grade and experience. This means a senior petty officer (E-6 or above) or SNCO, with a well-rounded maintenance background. Rare and unusual circumstances may require the use of other than a senior petty officer or SNCO. Under these circumstances, the most experienced personnel available as determined by the MO, may be temporarily employed as QARs. (Commander, Naval Air Forces, 2012, 7.4.3.2).

As a QAR, Marines are expected to undergo cross-OJT to facilitate the ability to supervise and inspect work on systems not specified by their MOS. The MRC deck or direction of the squadron's MO dictates which MAFS are required to be signed off by a QAR vice a CDQAR.

2. Timeline of Enlisted Service Related to Qualifications

As newly-minted aircraft maintainers arrive at the squadron, most will start gaining entry-level OJT qualifications. Occasionally, some new maintainers will fill non-maintenance-related billets within the squadron or sometimes outside of the squadron (typically referred to as fleet assistance program (FAP) billets). The entry-level maintainers will perform tasks such as aircraft fueling, towing, and corrosion control. The present study refers to many different types of entry-level qualifications as "less than CDI," meaning that these personnel have not become a CDI yet. Generally, CDI is the first major achievement marking mechanical experience and it is typically acquired during the end of the first enlistment and into the second enlistment. During the second enlistment, CDIs who remain committed to maintenance excellence generally transition into CDQARs. However, Marine headquarters often pressures aviation mechanics to leave the air wing temporarily to fill other necessary Marine Corps positions. This effect often leaves the squadron and the Marine at a disadvantage, requiring the squadron to refill/retrain the new missing position and requiring the Marine to refresh in their qualifications when returning to the air wing. When CDQARs have built a high amount of experience in a flying squadron, the squadron could make them a QAR, which will generally occur from the second enlistment to retirement. (Commander, Naval Air Forces, 2012).

3. Cost of Training Aviation Maintainers

The present study views the cost of training aviation maintainers from an economic perspective. Since the maintainer salary is paid regardless of performance, and typically no extra resources are used to train for qualifications, the only costs left to consider are opportunity costs. The opportunity cost of training for qualifications is included in the economic cost; that means each qualification costs what could have been accomplished had the maintainer not trained for the new qualification. Given data limitations, the opportunity cost of gaining qualifications cannot be calculated precisely in dollars, but it can be estimated.

The opportunity cost can be viewed from three different frames of reference: that of the Marine, that of the squadron, and that of the Marine Corps. The Marine may give up personal time and may be required to put in extra effort at work to gain a new qualification. Since Marines' willingness to pay for their next qualification comes in the form of extra time and effort, some will be more or less willing to pay for it. A squadron may have to temporarily allow a Marine to work on getting qualified as opposed to turning wrenches and fixing aircraft. It is assumed that the best maintainers are the ones recommended to attain the next qualification. In this case, a squadron's opportunity cost is becoming temporarily less efficient regarding maintenance while allowing the best maintainers to work on attaining their qualification. From the Marine Corps perspective, the result of increasing maintainer qualifications is a higher level of aircraft readiness (Kuginskie, 2012). The Corps pays for increased aircraft readiness by increasing maintainer replacement costs, decreasing non-aviation related training requirements, and decreasing the HQMC Special Duty Assignment (SDA) Screen Team (HSST) list requirements, among many other actions. If more qualified mechanics contribute toward higher readiness, the Marine Corps is trading aircraft readiness for a better state of basic training, recruiting, and non-aviation-related readiness. However, if there is no effect of qualifications on readiness, the Marine Corps should continue manpower staffing as is, not taking into account qualifications.

D. RETENTION

Enlisted Marines will typically face a decision to reenlist, extend, or separate approximately every 4 years. A typical first enlistment for aviation maintainers, however, is five years long, due to the lengthy training process that the technical job requires. The Marine must apply to reenlist and fill what is known as a “boat space” when accepted. USMC manpower allocates a certain number of boat spaces to each MOS every fiscal year, which is determined by manpower planners who continually strive to properly shape the Corps. If enough Marines reenlist in a given MOS, boat spaces run out; therefore, no more reenlistments may occur within that MOS that fiscal year. A Selective Reenlistment Bonus (SRB) for each MOS is determined and provides qualified enlistees a monetary lump-sum incentive payment. Each MOS SRB amount is based on the staffing needs of the MOS. Although the most common decisions when faced with reenlistment are to reenlist or voluntarily separate, in some cases Marines will extend their current contract to serve on a deployment or to extend their End of Active Service (EAS) into the next fiscal year to take advantage of changing reenlistment and SRB conditions. (Headquarters Marine Corp, 2004)

According to the Marine Corps Enlisted Retention and Career Development Program, “the retention effort to develop a career force with the proper grade, MOS, and experience is paramount” (Headquarters Marine Corp, 2004). Various force-shaping tools are used to allot appropriate personnel with billet vacancies. During force drawdowns, as the Marine Corps is currently undergoing, shaping tools, such as Voluntary Enlisted Early Release (VEERP) and Temporary Early Retirement Authority (TERA) incentivize early separation and retirement, respectively. During the build-up to the Operation Iraqi Freedom invasion, a program called “Stop loss” temporarily halted all Marines from exercising their EAS, to retain as many Marines as possible and maximize operational manpower. Current manpower-staffing programs are primarily designed to fill MOSs by grade and are only being indirectly influenced by qualifications. (Headquarters Marine Corp, 2004).

Most first-term enlisted Marines who separate do so right after their first commitment, becoming a civilian on their EAS date. The percentage of enlisted Marines who separate after subsequent tours declines drastically, most likely due to making the Marine Corps a career and planning for the twenty-year military retirement program.

This study focuses on Marines who are in their second or third reenlistment tour, as they are more likely to have the most qualifications and experience, and, therefore, the most potentially significant impact on aircraft readiness. After separation, it is difficult for a Marine to reenter the Marine Corps, except in times of force build up.

The Marine Corps sources non-operational tour billets—generally referred to as B-billets—for recruiting, drill instructors, Marine Security Guards (MSGs), and others, through what is known as the HSST program. B-billets normally incur a three-year tour outside of the MOS and deployable forces. The first step of HSST is to develop a list of Marines who are essentially pre-qualified to perform these duties. If pre-qualified for HSST, Marines will undergo further personnel screening to determine if a B-billet will be served at that time and if so, which B-billet. B-billets are viewed as favorable for career-minded Marines wanting to be competitive for promotion boards and other Marine Corps-wide selection processes, as this Enlisted Career Counseling Newsletter states:

> Consideration must be given to the timing leaving the MOS mainstream. If possible, you must consider if you have been able to show quality performance in professional maturity. You must also consider the choices available to you and which may make you most competitive. The five special duties; Recruiting, Drill Instructor, Marine Security Guard, Security Forces, Marine Combat Instructor are the best choices to add muscle to your record. Those who are on or have completed any of the five Special Duties will be precept as Highly Competitive. This does not mean that one can rely solely on the strength of a Special Duty to make him/her more competitive. If you have shown strength in your primary duties, a Special Duty can be like a “Force Multiplier” that will definitely accelerate your performance value. (Collins, 2014).

It should be noted that, as B-billets are staffed, a unit loses the qualifications possessed by that Marine maintainer. Also, HSST generally targets second-term Marines, which is the same population this thesis examines due to their assumed impact on readiness. Some actions have been taken to lessen the burden on critical MOSs, such as how the Marine Aviation Plan states, “B-billets for officers and enlisted will be staffed by MMOA and MMEA from the MV-22 community as the health of those populations allows” (Headquarters Marine Corps, 2014, 3.8.5).

Besides voluntary separation and HSST, as forms of enlisted aviation manpower retention loss, other forms of personnel loss can occur as well. Some of these losses are due to punitive actions, which may force a Marine to involuntarily separate. Also, if enough Marines do not voluntarily separate, retention boards will convene to involuntarily separate selected personnel, based on their comparative performance. Finally, some enlisted Marines leave the operating forces to join officer accession programs or, perhaps, other non-operational billets other than B-billets.

Enlisted aviation mechanics are often faced with separation, HSST, and other non-operational billet decisions. The Marine Corps needs to maintain its personnel structure and requires certain personnel to leave or fill non-MOS billets; however, this structure may not be optimum to the technical aircraft maintenance job field. This thesis employs a systematic analysis, using data-driven statistical techniques to formulate a recommended qualification structure, given an expected readiness level for Marine aviation.

III. LITERATURE REVIEW

This chapter reviews a limited selection of previous research that contributed directly toward designing the analytical framework and approach used for the present study. The chapter divides this narrow group of previous work into two categories: USMC Aviation Readiness; and Measuring the Effect of Various Factors on Readiness.

A. USMC AVIATION READINESS

Kuginskie finds support for the existence of the NAE in his 2012 Master's thesis, *The Naval Aviation Enterprise Type/Model/Series Team and its effect on AH-1W Readiness,* as he investigates the bigger picture of aviation readiness (Kuginskie, 2012). Kuginskie (2012) states:

> By incorporating maintainer, aircraft and aircrew readiness with the supporting establishment into a process managed by the stakeholders, NAE created a holistic process that has a positive effect on AH-1W readiness. Through inherent transparency, leaders can make well-informed decisions with direct effects. Reduced aircraft availability and budget combined with increased readiness requirements, the Marine Corps will continue to rely on NAE to manage its aviation readiness. (p. 21)

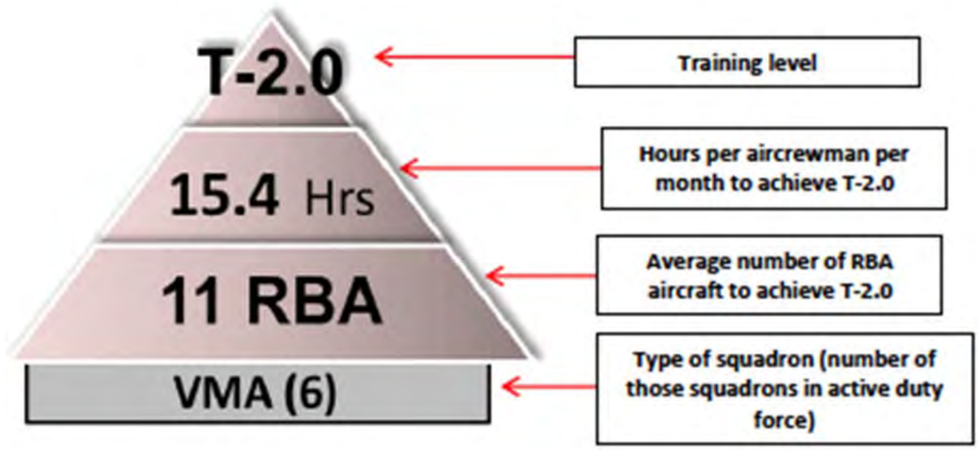
NAE addresses readiness through the same three essential elements as Defense Readiness Reporting System (DRRS): people, equipment, and training. When referring to how NAE built its computerized aviation readiness system, Kuginskie (2012) finds that NAE uses "DRRS principles of personnel, equipment supply, equipment condition and training as the baseline principles to improve a squadron's readiness," (p. 6). Kuginskie's study concludes that NAE was the first major success in unifying and providing transparency to the aviation readiness process, allowing commanders at various levels to make better-informed decisions (Kuginskie, 2012).

Kuginskie's thesis views readiness as a function of people, equipment, and training, which are the same factors utilized in the present study. Maintainer qualifications can be viewed as an input and output into this system. For example, it requires a willing individual, available equipment upon which to gain experience, and training procedures to create a qualified maintainer. At the same time, a qualified maintainer will help to develop junior maintainer qualifications, fix aircraft, and ultimately contribute to a higher state of readiness. Kuginskie's (2012) qualitative analysis could be put to the test by quantifying qualifications and measuring their effects on readiness. Due to NAE's holistic database, the present study utilizes NAE's data to observe the relationship between qualifications and readiness and to quantify the effects of qualifications on readiness.

The 2015 Marine Aviation Plan affirms that aviation readiness is the strategic goal of Marine aviation, as shown in Figure 5, and increased aircraft readiness is considered the foundation of Marine aviation readiness (Headquarters Marine Corps, 2014). HQMC Aviation use Table 2 to illustrate the current RBA readiness standard for various aviation squadrons. The plan presents a serial pyramid process that starts with ready basic aircraft at the base. The aircraft are then flown to provide the requisite training. The metrics used in this process are RBA, flight hours, and a calculated training-level (T-level). These metrics can currently be obtained from AMSRR, DECKPLATE, and DRRS. It should be emphasized here that aircraft readiness and aviation readiness are related, yet also treated as distinct, that is, aircraft readiness is the foundation for what should translate into aviation readiness. As stated in the Marine Aviation Plan, "we need to increase the amount of time our aviators spend in the air" (Headquarters Marine Corps, 2014, p. 4). From a maintenance perspective, this plan creates an initiative to meet or exceed RBA. It can be inferred that RBA is the foundation of readiness, which this thesis intends to analyze as a dependent variable. Although the 2015 Marine Aviation plan measures aircraft readiness in terms of RBA, other studies often utilize MC as a similar metric (Headquarters Marine Corps, 2014).

The findings from the 2012 Kuginskie study and the 2015 Marine Aviation Plan establish a premise that aviation readiness results from aircraft readiness. Further, RBA and MC are a result of people. Maintainer qualifications are a fusion of people and training. The analytical approach in the present study attempts to account for the interaction of qualifications on readiness metrics, such as RBA and MC.

Figure 5. 2015 HQMC Aviation Plan, Aviation Combat Readiness Pyramid



Source: Headquarters Marine Corps. (2014, Sep). Marine aviation plan: 2015. Washington, DC: Author

Table 2. 2015 HQMC Aviation Plan, RBA Readiness Standards

SQDN	T/M/S	Hrs per Pilot/WSO/ECMO	Primary Mission Aircraft Authorized (PMAA)	Flight Line Entitlement (FLE) per Sqdn	RBA Required for T-2.0
HMH	CH-53E	16.5	16	13	8
HMLA	AH-1W	15.8	18	13	10
	UH-1Y*	20.4/17.8	9/12	9/12	6/7
	AH-1Z*	18.2	15	13**	9
HMM	CH-46E	22.2	12	12	
VMM	MV-22B	16.8	12	12	7
VMGR	KC-130J	22.5	15	15	9
VMAQ	EA-6B	15.1	5	4	3
VMA	AV-8B	15.4	14	14	11
VMFA	F-35	10.2	16	16	10
VMFA	F/A-18C	15.8	12	10	8
VMFA(AW)	F/A-18D	16.6	12	10	8

Source: Headquarters Marine Corps. (2014, Sep). Marine aviation plan: 2015. Washington, DC: Author

B. MEASURING THE EFFECT OF VARIOUS FACTORS ON READINESS

In 2005, Chesterton analyzed predictors of aviation maintenance performance in his thesis, *Explanatory Factors for Marine Corps Aviation Maintenance Performance*. Chesterton (2005) collected data across USMC fixed-wing squadrons, and over time, to use the data in a regression analysis on the effects of man-hours per maintenance action. Chesterton (2005) explains the basis of his study as follows:

> The performance and expertise of Naval aviation squadrons is closely tied to the performance of their maintenance teams. Aircraft that cannot fly or operate in a fully functional manner due to inadequate maintenance seriously harms mission capability. It is useful, therefore to identify factors related to a squadron's mission, and the personnel and assets at its disposal, which help to explain the performance of their maintainers. (p. xv)

Chesterton's 2005 study uses man-hours per maintenance action due to its direct relationship with maintainers that also exclude external factors. The regression model used by Chesterton (2005) is presented in Figure 6.

Figure 6. Chesterton Regression Model

$$\ln Y_{s,t} = \beta_0 + \beta_1 X_{1,s,t} + \beta_2 X_{2,s,t} + \beta_3 X_{3,s,t} + \beta_4 X_{4,s,t} + \beta_5 X_{5,s,t} + \varepsilon_{s,t}$$

Where

$Y_{s,t}$ = man-hours per maintenance action, squadron s, month t
$X_{1,s,t}$ = type equipment code
$X_{2,s,t}$ = average aircraft hours in service
$X_{3,s,t}$ = location
$X_{4,s,t}$ = months in squadron, median
$X_{5,s,t}$ = deployment status
$\varepsilon_{s,t}$ = residual
k = number of variables
s = squadron
t = month

Source: Chesterton, G. L. (2005). Explanatory factors for Marine Corps aviation maintenance performance (Master's thesis). Retrieved from http://calhoun.nps.edu/handle/10945/2113

Chesterton's regression analysis models readiness as a function of descriptive variables from Marine Corps Total Force System (MCTFS) to explain man-hours per maintenance action. The data Chesterton pulled from MCTFS include MOS, date arrived at current duty station, date departed from previous duty station, rank, and months served on active duty. Chesterton uses two experience variables. The first experience variable was created by aggregating months of service data into lower, medium, and upper thirds. The second experience variable was created by aggregating the months of squadron data into lower, medium, and upper thirds. Chesterton controls for aircraft type and aging by adding to the list of explanatory, control variables type of aircraft, airframe hours, and airframe months in service. Number of technical support assists and squadron locations are also included as control variables. Table 3 displays a complete list of variables used in the study by Chesterton (2005).

Table 3. Chesterton Regression Variables

Data Source	Group	Metric	Type
NALCOMIS	Measures of Utilization	Flights and Flight Hours	Performance
		Utilization	Performance
	Measures of Availability	NMCM	Performance
		NMCS	Performance
	Measures of Maintainability	Man-hours per flight hour	Performance
		Man-hours per maintenance action	Performance
		TD hours	Performance
	Measures of Reliability	Cannibalizations per flight hour	Performance
		A799s per flight hour	Performance
MCTFS	Measures of Experience	Months in service quartiles	Descriptive
		Months in squadron quartiles	Descriptive
	Measure of Stability	Turnover rate	Descriptive
AIRRS	Aircraft Type	Type equipment code	Descriptive
	Measures of Aircraft Age	Airframe hours	Descriptive
		Airframe months in service	Descriptive
ELAR	Measure of ETS Activity	Records per month	Descriptive
Various	Measure of Ops Tempo	Deployment Status	Descriptive
N/A	Measure of Environment	Location	Descriptive

Source: Chesterton, G. L. (2005). Explanatory factors for Marine Corps aviation maintenance performance (Master's thesis). Retrieved from http://calhoun.nps.edu/handle/10945/2113

Whereas Chesterton uses NALCOMIS for his dependent variables, the present study employs AMSRR and DECKPLATE because NALCOMIS is incorporated into DECKPLATE. AMSRR is used for RBA percentage and DECKPLATE for MC, both of which are good performance indicators of a squadron. This study is essentially using the same information in the time-series model because NALCOMIS feeds into DECKPLATE. Although MC is obtained from DECKPLATE, readiness is also obtained by RBA, which AMSRR includes in its reports.

For independent, explanatory variables, this study uses MCTFS variables from TFDW that are similar to variables used in Chesterton's (2005) thesis. The MCTFS variables help to control for personnel factors. Chesterton would have likely included aviation qualifications, but they were still in paper jackets at that time, and unavailable for his study. These qualifications are now available in ASM; consequently, the present study includes them in the analysis.

IV. DATA AND DESCRIPTIVE STATISTICS

The data used in this thesis come from multiple sources, merged into two distinct data sets: a cross-sectional data set describing RBA and a time-series data set describing MC. The cross-sectional database was derived from TFDW, AMS, and AMSRR. The time-series data set was derived from a readiness and manpower database that HQMC Naval Aviation Enterprise (NAE) provided.

The original effort of the present study was to build the cross-sectional database with a time element; however, archives for qualifications in ASM do not exist at this time. Therefore, the cross-sectional database is not robust in describing RBA from qualifications, but it is substantial in describing human factors behind the qualifications. The time-series data became available during the course of this study, and include both qualifications and MC. These data were available across time, from 2012 to 2015, generating time-series data with a robust description of MC (similar to RBA), and fitting the purpose of the study. Due to the constraints on data availability discussed above, the cross-sectional data set is used primarily for descriptive statistics of the population at a given time, while the time-series data are used primarily to investigate the effect of qualifications on readiness using multivariate regression analysis. It is important to note that the cross-sectional data set offers readiness in terms of RBA, while the time-series data set offers readiness in terms of MC.

A. CROSS-SECTIONAL DATA

Each snapshot observation represents a maintainer, containing personnel, qualifications, and squadron readiness data from TFDW and ASM. In addition, RBA readiness data from AMSRR were merged into each observation aligned to their respective squadron. TFDW and ASM used a unique key identifier of the (unit of observation) for merging. The end result is a database that contains data on personnel qualifications, aligned with squadrons and an associated readiness score.

1. Data Sources

Three data sources were selected to provide information regarding personnel, qualifications held, and readiness data. Each of these databases is independent, managed by different organizations within the USMC and Navy. By merging data from TFDW and ASM, the data set describes personnel-related factors, such as marital status, Armed Forces Qualification Test (AFQT) score, years of service, rank, and qualifications. Further, adding RBA data for each squadron allows the researchers to study the relation between qualifications and personnel factors on aircraft readiness. TFDW and ASM provide a snapshot in July 2015, while AMSRR provides an average RBA across 2 ½ months starting in July 2015.

a. TFDW

TFDW is able to provide a snapshot once per month of every Marine's personnel file from a system called Marine Corps Total Force System (MCTFS). MCTFS information is updated in real-time and captures each Marine's personnel and training information. TFDW is a tool that allows for historical MCTFS data to be pulled. All personnel data assumed to be relevant to qualifications or RBA are used in the present study.

b. ASM

ASM is updated in real-time; there is currently no capability to provide archived ASM data. If historical ASM data were available, the cross-sectional database created would be time-series, vastly increasing the robustness of the analysis of qualifications and readiness. Despite this data limitation, ASM data can provide cross-sectional insight of aviation qualifications from the date/time that the data were pulled. All qualification data for every Marine in the ASM database for the MOSs and squadron types specified are used in the analysis.

c. AMSRR

AMSRR is able to provide aircraft readiness data in the form of a squadron RBA percentage for each flying squadron to which Marines are attached in ASM and TFDW.

AMSRR is also able to produce an NMCS percentage for the same squadrons, which is needed to include the effect of non-ready aircraft awaiting supply. Entries into AMSRR are made every day the squadron is operational. It is assumed a single 24-hour RBA score is not a fair representation of squadron RBA when judging the overall effects of qualifications. For this reason, RBA is an average derived in AMSRR across a 2 ½ month timeline. NMCS was aggregated in the same manner as RBA. The average squadron RBA and NMCS are used and assigned to each member within that squadron.

2. Variables, Data Cleaning, and data Coding

Microsoft Excel was used to import and merge data from TFDW, ASM, and AMSRR. The personnel observations contained the necessary fields in all three databases. One unit of observation in the final data set consisted of an enlisted Marine with a record in the TFDW file who also had an ASM record, and who belonged to a squadron listed in Table 6.

a. Variables

TFDW provided personnel factors that are assumed to be correlated with qualifications or readiness. Table 4 displays the MOSs of interest. Table 5 shows the TFDW data fields that were imported. TFDW data for this study are a single snapshot from July 2015. All qualification data were received from an ASM data manager for the 12 specified MOSs in Table 4 in July 2015. The ASM data fields include the following: duty billet title, status, and unit.

Aviation maintenance personnel qualification data were provided by ASM. ASM provided a data field labeled “duty billet,” which gives a qualification for each observation, selected from a standardized list of qualifications. Many mechanics have multiple qualifications, resulting in multiple observations for a single mechanic. The “status” data field states whether the qualification held is listed as active or inactive, indicating whether the mechanic is actively holding/practicing that particular qualification or not. The “unit” data field shows what squadron for which the mechanic is currently working. The 12 military occupational specialties (MOSs), shown in Table 4 are assumed to have the most impact on aviation readiness. Specifically, these MOSs have the most direct mechanic interaction with the aircraft, on a regular basis. Since the TFDW provides a July 2015 snapshot, the ASM data were also taken from July 2015.

An average squadron RBA and NMCS percentage was provided by AMSRR, and it is assigned to each observation in the database, respective to the squadron. Data for two units, VMM-164 & VMM-774, were not used in the analysis due to mid-transition of CH-46 to MV-22, as noted in Table 6. Average RBA percentage is a single data field that describes directly the squadron from which it was taken. RBA percentage is recorded on a daily basis, but this study uses the squadron daily average based on data from 31 July to 18 October 2015. It is assumed that maintenance qualifications affect RBA contemporaneously, as well as in the near future. Due to this assumption, the average RBA was calculated starting from the time that the ASM qualifications were received and for the subsequent 2 1/2 months. RBA and NMCS percentage data were only obtained for each squadron that was observed in the TFDW and AMS datasets. Table 6 contains the list of squadrons observed.

Table 4. MOSs of Interest

MOS	Title
6113	Helicopter Mechanic, CH-53
6114	Helicopter Mechanic, UH/AH-1
6116	Tiltrotor Mechanic, MV-22
6153	Helicopter Airframe Mechanic, CH-53
6154	Helicopter Airframe Mechanic, UH/AH-1
6156	Tiltrotor Airframe Mechanic, MV-22
6173	Helicopter Crew Chief, CH-53
6174	Helicopter Crew Chief, UH-1
6176	Tiltrotor Crew Chief, MV-22
6323	Aircraft Avionics Technician, CH-53
6324	Aircraft Avionics Technician, UH/AH-1
6326	Aircraft Avionics Technician, MV-22

Table 5. TFDW Data Fields and Descriptions

TFDW Data Field	Description
TFDW Snapshot Date	Date data was pulled
PMOS	Primary MOS Code
Grade	Current grade
Race	Race Code
Years of Service	Number of years in service
AFQT Score	AFQT score
Marital Status Code	Marital Status Code
Number of Dependents	Number of dependents

Table 6. AMSRR Squadrons Data

Unit (Squadron) **Indicates partially or fully deployed*	**Aircraft Type**
HMH-361	CH-53
HMH-366	CH-53
HMH-461	CH-53
HMH-462*	CH-53
HMH-463*	CH-53
HMH-464	CH-53
HMH-465	CH-53
HMH-466	CH-53
HMH-772	CH-53
HMHT-302	CH-53
HMLA-167	UH/AH-1
HMLA-169	UH/AH-1
HMLA-267	UH/AH-1
HMLA-269*	UH/AH-1
HMLA-367*	UH/AH-1
HMLA-369	UH/AH-1
HMLA-467	UH/AH-1
HMLA-469	UH/AH-1
HMLA-773	UH/AH-1
HMLA-773/A	UH/AH-1
HMLA-773/B	UH/AH-1
HMLAT-303	UH/AH-1
VMM-162*	MV-22
VMM-163	MV-22
VMM-164 (Did not use)	MV-22
VMM-165*	MV-22
VMM-166	MV-22
VMM-261*	MV-22
VMM-262	MV-22
VMM-263	MV-22
VMM-264	MV-22
VMM-265*	MV-22
VMM-266	MV-22
VMM-268*	MV-22
VMM-363	MV-22
VMM-364	MV-22
VMM-365	MV-22
VMM-764	MV-22
VMM-774 (Did not use)	MV-22
VMMT-204	MV-22

b. Data Cleaning

TFDW originally contained data fields that were not used in the analysis due to incomplete information or data that were redundant (included elsewhere). Certain data fields, such as reporting unit code (RUC), were mostly blank and thus deleted. Although data fields such as RUC were inconsistent, other fields, such as geographical location code, were very consistent and used to determine location. Rank and pay-grade were both reported, but only rank was used due to information overlap. After careful screening, the variables used in the analysis are identified in Table 5.

The main goal of ASM was to identify four levels of qualifications that are assumed to have an effect on aviation readiness. The four levels of qualifications were found in the duty billet field in written form. To be able to use that information in the analysis, these written fields were distilled into the following fields: < CDI (later referred to as "lessthanCDI"), CDI, CDQAR, and QAR. Many mechanics possess multiple qualifications; therefore, ASM displayed several rows of data for each mechanic. An assumption was made that the highest active qualification held by each mechanic is the most significant one. Therefore, duplicate files were removed to keep only the highest active qualification for each individual. If an individual had no active qualifications, the highest inactive qualification was kept. It was assumed that inactive qualifications provide a form of human capital, since the skill/knowledge does not disappear when not being directly utilized on aircraft at that time. The ASM data ready for merging with TFDW contained a single row of data for each unique ID identifying an enlisted Marine, their highest qualification, active status, MOS, and squadron.

RBA was reported from AMSRR for the time period of 31 July to 18 Oct 2015. In the cases where a unit was partially or fully deployed during this time period, RBA data had to be aggregated due to squadrons reporting in AMSRR from multiple locations or changed operational status during the time period reported. Aggregating squadron RBA required taking the total number of planes in any given day and the number of planes that were RBA for the same day. Daily aggregated squadron RBA was then calculated by dividing the total number of planes that were RBA by number of planes in reporting, for each day of the reporting time period. After creating the daily RBA percentage, the average RBA percentage was calculated for the specified 2 ½-month period. Two squadrons reported outlier RBA percentages, requiring further investigation. It was determined that VMM-164 is currently being established, so its RBA reporting is not considered a fair representation; consequently, these data were not used in the analysis. VMM-774 was engaged in a transition from having CH-46 helicopters to MV-22s; these data were also excluded from the analysis. After cleaning RBA data, 38 squadrons had RBA averages that were kept for analysis and imported into the cross-sectional database.

c. Data Coding

Binary variables were created to describe each non-numeral field of interest. For example, the CDI field is represented by a binary variable that takes the value of 1 if a Marine’s highest qualification is CDI, and 0 otherwise. Binary fields were created to describe the following non-numeric fields: < CDI, CDI, CDQAR, QAR, MOS, Rank, Married, non-commissioned officer (NCO), and staff non-commissioned officer (SNCO). NCOs and SNCOs are often viewed as having a significant impact in the Marine Corps, so these binary variables were generated in Stata by summing Cpl + Sgt and SSgt + GySgt, respectively. These numeric variables were retained in their original form, which included: RBA percentage, NMCS percentage, Years of Service, AFQT Score, and number of dependents. Table 7 shows a list of the variables used and their definitions.

Table 7. Cross-Sectional Variables Definition Table

Variables	**Definition**
< CDI	less than a CDI
CDI	CDI
CDQAR	CDQAR
QAR	QAR
Highest_Qual	Highest Qualification (1=<CDI to 4=QAR)
Pvt	Private
PFC	Private First Class
LCpl	Lance Corporal
Cpl	Corporal
Sgt	Sergeant
SSgt	Staff Sergeant
GySgt	Gunnery Sergeant

Active	Qualification is Active
AFQT_SCORE	AFQT overall test score
Married	Married
Number of Dependents	Number of dependents
White	Race is White
YOS	Years of service
RBAP	RBA percentage
HMH	Heavy helicopter squadron
HMLA	Light attack helicopter squadron
VMM	Tiltrotor squadron
activeCDI	Active CDI interaction variable
activeCDQAR	Active CDQAR interaction variable
activeQAR	Active QAR interaction variable
NMCS	Non-mission capable supply percentage
NCO	Non-commissioned officer
SNCO	Staff non-commissioned officer

3. Summary Statistics

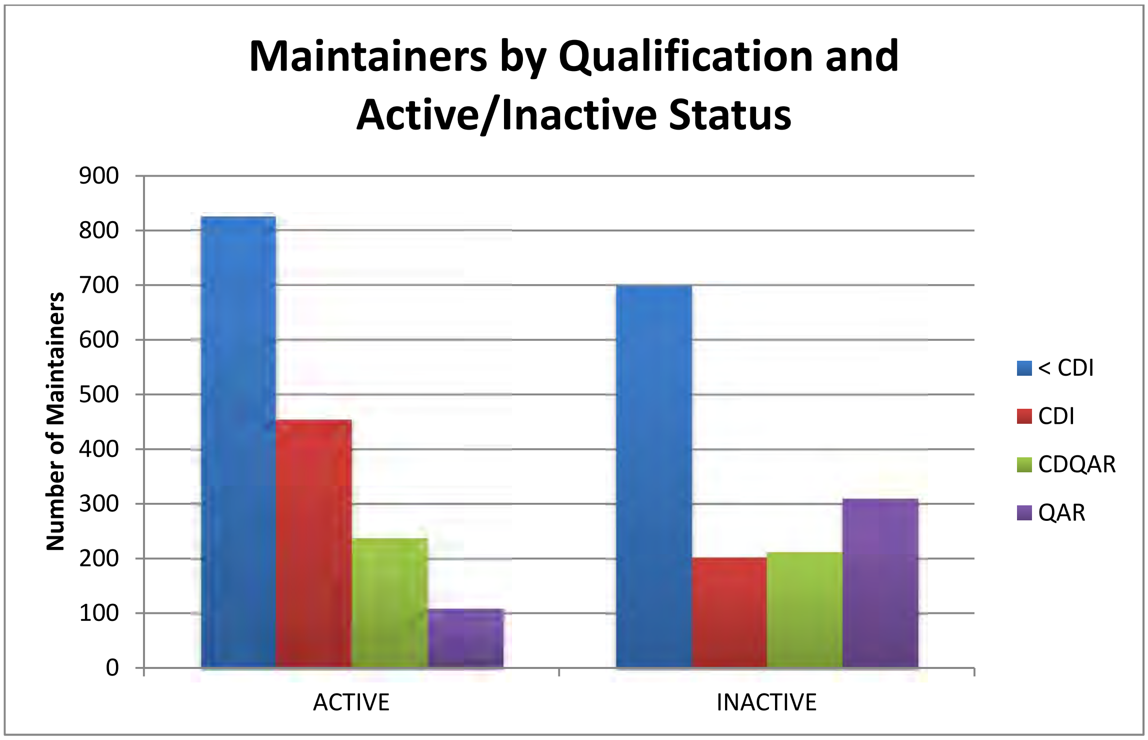
After merging TFDW, ASM, and AMSRR data, the resulting data set was used to derive descriptive statistics. All summary statistics confirm the initial assumptions of the authors of this thesis. A total of 2,966 personnel observations describing their squadron RBA were used in the cross-sectional analysis, as shown in Table 8. The cross-sectional data allow for a description of the proportion of qualified Marines, which also shows the following: about one-half of the maintainers of interest in a helicopter or tilt-rotor squadron are < CDI; about 22% are CDIs; 15% are CDQARs; and 14% are QARs. It is appropriate for less-than-CDI to be the largest sub-population, because most work that is accomplished in a squadron is labor-oriented, supervised by a CDI or higher. The highest qualification variable refers to the number assigned to qualifications, ranging from 1 being less than CDI to 4 being QAR. Some interesting averages include the following: AFQT score of 67 (“above average”); 85% White; 5.7 Years of Service; and 57% NCO.

Table 8. Cross-Sectional Model Summary Statistics (2,966 observations)

Variable	**Mean**	**Standard Deviation**	**Min**	**Max**
< CDI	0.498	0.500	0	1
CDI	0.218	0.413	0	1
CDQAR	0.147	0.354	0	1
QAR	0.137	0.343	0	1
Highest_Qual	1.922	1.089	1	4
Pvt	0.000337	0.0184	0	1
PFC	0.00607	0.0777	0	1
LCpl	0.232	0.422	0	1
Cpl	0.312	0.463	0	1
Sgt	0.263	0.441	0	1
SSgt	0.118	0.323	0	1
GySgt	0.0684	0.253	0	1
Active	0.534	0.499	0	1
AFQT_SCORE	67.27	15.20	26	99
Married	0.570	0.495	0	1
Number of Dependents	1.055	1.259	0	7
White	0.850	0.357	0	1
YOS	5.737	4.445	0	24
RBAP	0.464	0.0985	0.256	0.690
HMH	0.307	0.461	0	1
HMLA	0.416	0.493	0	1
VMM	0.277	0.447	0	1
activeCDI	0.151	0.358	0	1
activeCDQAR	0.0775	0.268	0	1
activeQAR	0.0364	0.187	0	1
NMCS	0.275	0.0799	0.0940	0.442
NCO	0.575	0.494	0	1
SNCO	0.186	0.390	0	1

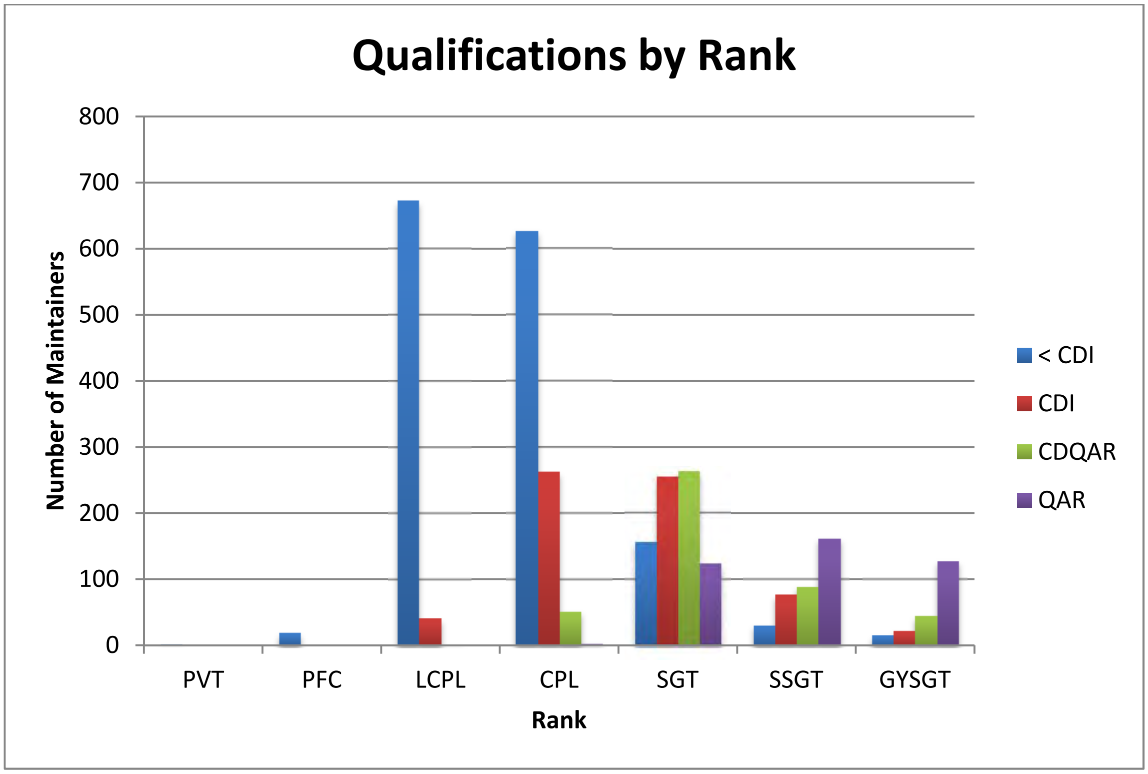
The < CDI variable, as presented in Figure 10, shows that the largest qualification population are less than a CDI, and that the number of qualified Marines in active status tends to decrease as the qualification increases. Another interesting observation is that, contrary to the other qualifications, there are more inactive QARs than active. This is possibly due to QAR being a temporary qualification that reverts back to CDQAR. Another possible explanation for this is that it is a terminal qualification, perhaps providing the squadron with a pool of inactive QARs that can be easily activated when needed. This study assumes that inactive qualifications are a form of human capital that can still be leveraged for their mechanical expertise, albeit indirectly through regular conversations and interaction. “Less than CDI—Active” qualifications has the most Marines, probably due to many minor qualifications that are needed to do basic work. “Less than CDI—Inactive” qualifications has the second most Marines, who have no qualifications, probably due to being very inexperienced. One can easily observe from the overall squadron qualification composition, as shown in Figure 7, that most maintainers fall into the lower qualifications.

Figure 7. Maintainers by Qualification and Active/Inactive Status



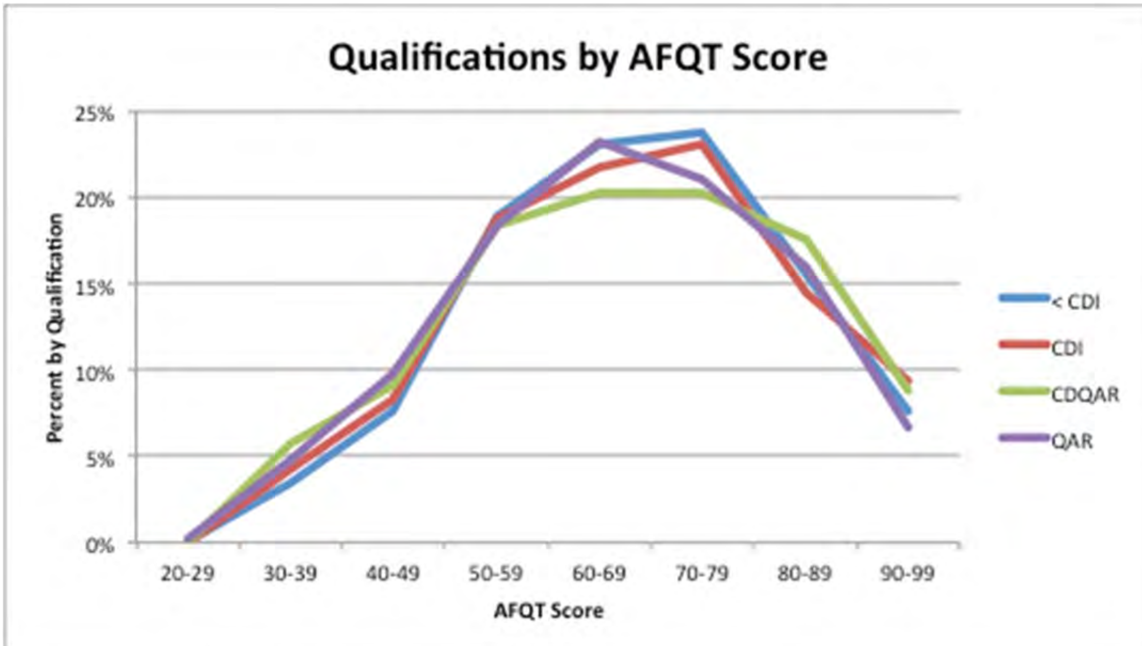
Qualifications by rank, as illustrated in Figure 8, also support the initial assumption that maintainers in junior ranks make up most of the junior qualification populations. Conversely, those in senior ranks possess most CDQAR and QAR qualifications. Figure 8 provides a good visual depiction of the proportion of maintainers who do not fall in the typical range. For example, although most Lance Corporals (LCpls) are less than CDI, a small portion of them are CDIs, possibly suggesting high achievement. At the same time, some SNCOs (Staff Sergeants and above) are less qualified than a majority of their peers who are CDQARs or QARs.

Figure 8. Qualifications by Rank



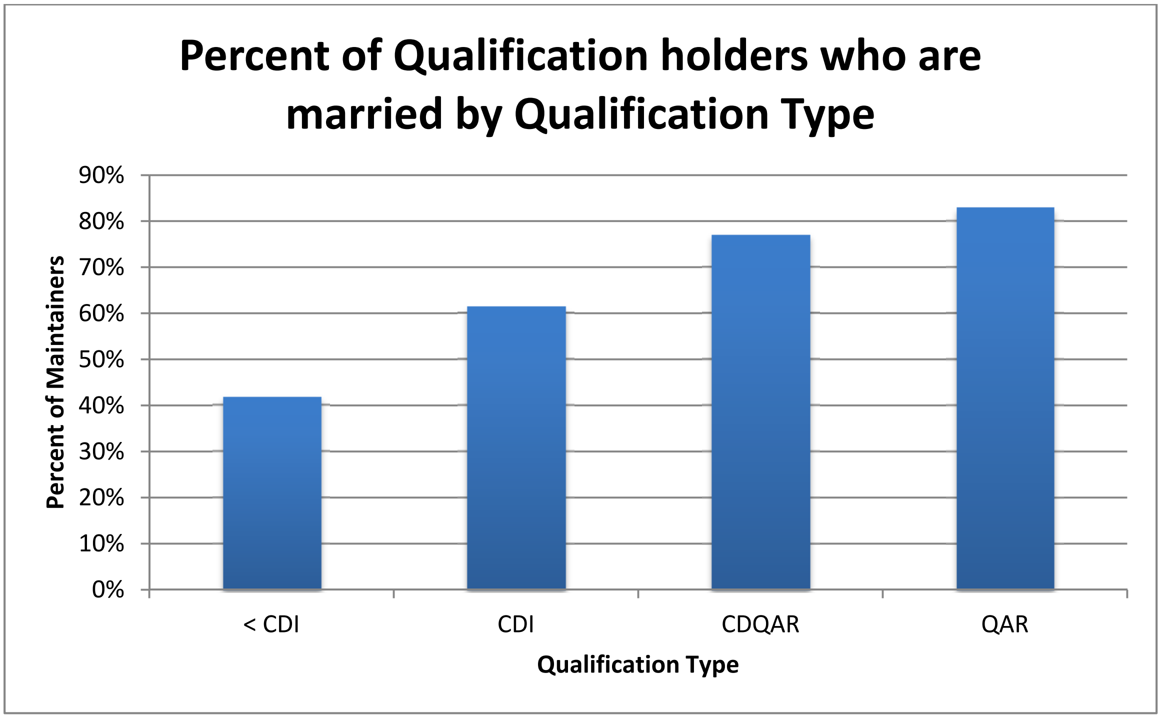
A cross-tabulation of qualifications by AFQT score is shown in Figure 9. It is interesting to see roughly a normal distribution of AFQT scores by the total percentage of qualifications possessed. It should be noted here that the AFQT is a composite of four subtests on the Armed Services Vocational Aptitude Battery. The AFQT, along with other subtest composite scores, are used by recruiters to help place Marine recruits in training for an MOS. This is due to the fact that these aptitude test scores generally predict a recruit's "trainability." Some Marine Corps MOSs, especially the more technical ones, are very selective due to the higher level of required training and their associated costs. AFQT scores are used in the present study as an indicator of general aptitude among aviation Marines. It should also be noted that the average score for the AFQT, based on a national sample of youth, is set at 50. The percentages of maintainers by qualifications, as seen in Figure 9, tend to peak in the above-average range of scores on the AFQT. A possible explanation for scores below the normal recruiting limit could be due to different past policies or lateral transfers.

Figure 9. Qualifications by AFQT Score



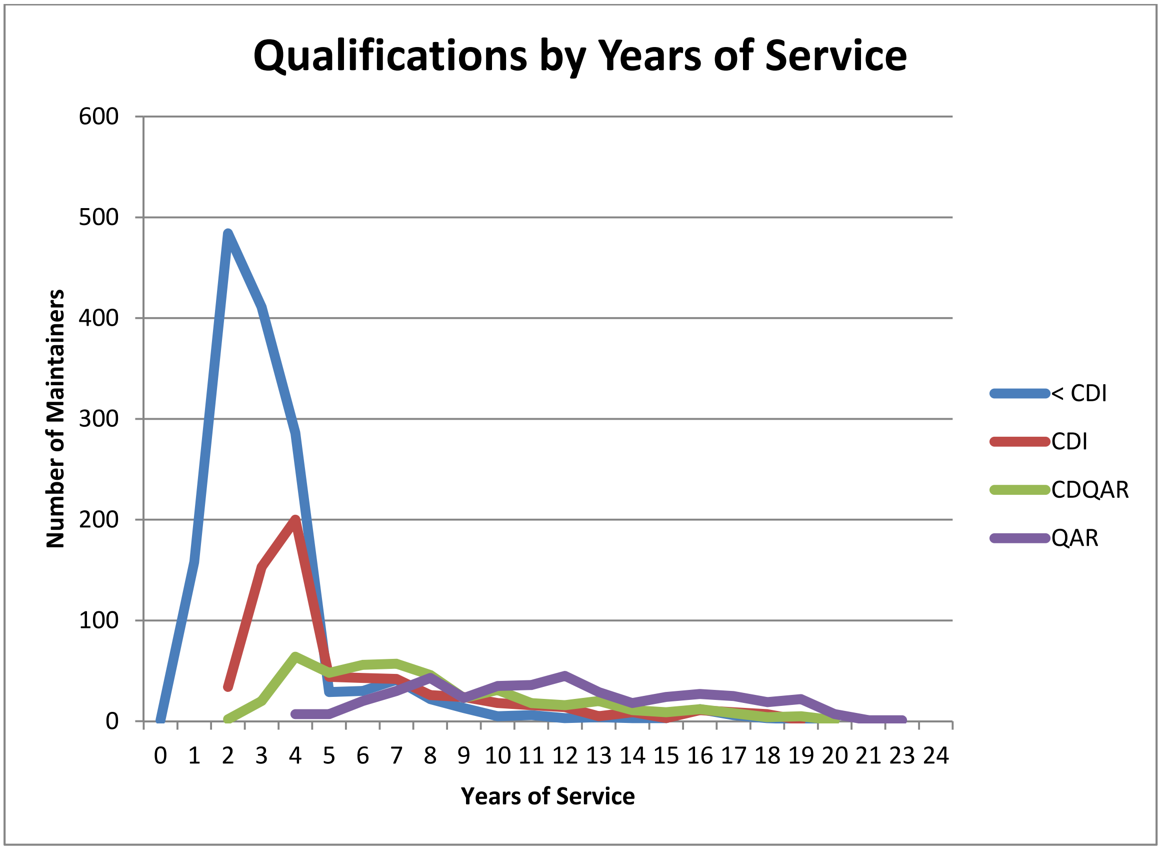
The percent of qualification holders who are married also resembles what one would reasonably expect, as shown in Figure 10. As Marines advance in qualifications, they generally become more senior in age and status within the Marine Corps, and are more likely to be married. This could also possibly suggest a careerist mindset possessed by married Marines. The present analysis will test the hypothesis that marital status is correlated with qualifications. Further, it is assumed that other factors related to marital status, aside from age, such as determination and motivation, an unobserved variable, might be related to qualifications and to the likelihood that a Marine might be married.

Figure 10. Percent of Qualification Holders who are Married by Qualification Type



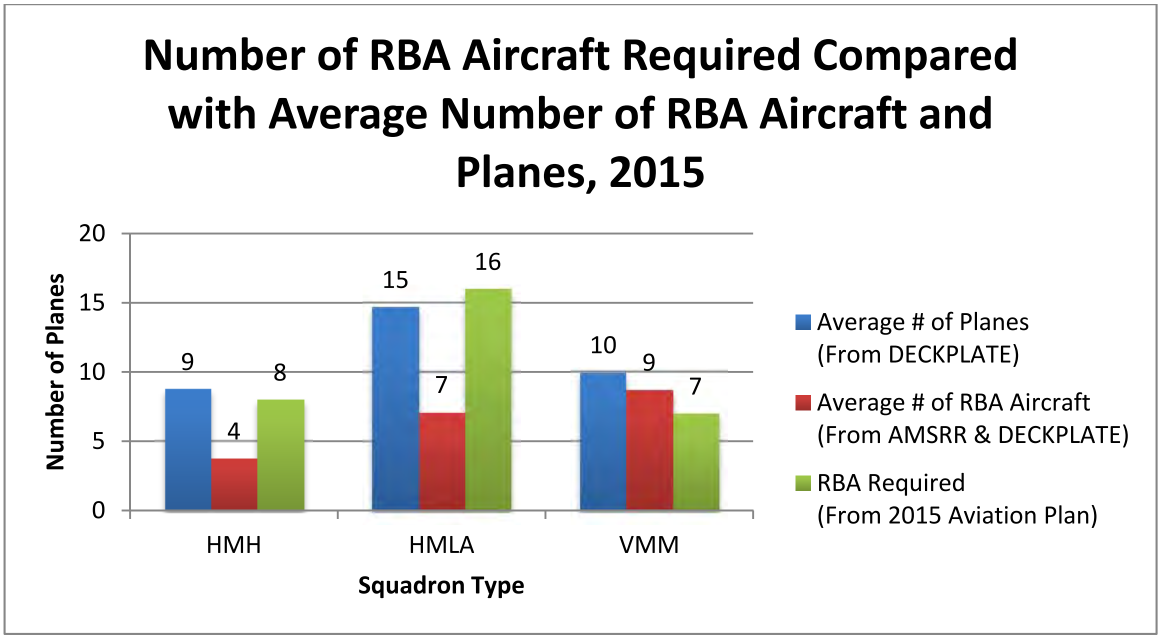
The overall number of qualifications and population of enlisted aviation Marines decline over years of service. The personnel decline aligns well with the effect of force-shaping over successive enlistments. Most aviation mechanics have an initial five-year enlistment contract. Figure 11 depicts a severe population loss at the five-year mark. Figure 11 also indicates that most of the CDI personnel are in a first enlistment, most of the CDQAR personnel are in a second enlistment (5–9 years of service), and most of the QAR personnel are beyond their second enlistment.

Figure 11. Number of Qualification Holders by Years of Service



The analysis also takes into account RBA required and historical RBA, especially because the 2015 Marine Aviation Plan seeks to drive RBA required as a benchmark for readiness (Headquarters Marine Corps, 2014, 1.3). As shown in Figure 12, on average, only VMM squadrons meet RBA. This phenomenon is puzzling and is the opposite of HMLAs and HMHs. DECKPLATE data show that the average number with HMLAs is 15 when the minimum required RBA is 16. To derive the average RBA in this example, the average percentage of RBA in each squadron type from AMSRR was multiplied by the average number of planes in each squadron type from DECKPLATE.

Figure 12. Number of RBA Aircraft Required Compared with Average Number of RBA Aircraft and Planes, 2015



B. TIME-SERIES

The time-series data stem from DECKPLATE and MACCRAT, two systems maintained by the Navy and Marine Corps, respectively. These data bases both record entries once per month. The targeted time-series data set essentially consists of aircraft readiness data in terms of MC through DECKPLATE, and qualification data, measured by number of CDIs, CDQARs, and QARs through MACCRAT.

1. Data Sources

Both DECKPLATE and MACCRAT data sources are originating from NAE. Although NAE maintains both databases, they are independent systems that are maintained by different staffing departments. Despite these databases being autonomous, they are both similar in design, making merging a simpler process than in the cross-sectional data set.

a. DECKPLATE

DECKPLATE is a reporting system for all of the NAE. It provides "capabilities to effectively obtain readiness data in a near real-time environment, as well as, history data for trend analysis and records reconstruction" ("About DECKPLATE," n.d.). According to the NAMP, "DECKPLATE is designed to provide a single centralized and consolidated data warehouse for inventory, maintenance, and readiness data for Navy and Marine Corps aircraft. Comprehensive aircraft maintenance and flight information is collected and combined to provide visibility of aircraft engines and aeronautical components across the NAE" (Commander, Naval Air Forces, 2012). The data used in this study were obtained through MAINT 2 reports. Each squadron uses MAINT 2 report operational status, flight hours, and respective MC/NMC/PMC hours (D. L. Edgmon, personal communication, November 4, 2015). Data provided by DECKPLATE for the study have monthly observations for each squadron from January 2012 to September 2015.

b. Marine Aviation Commander's Current Readiness Assessment Tool (MACCRAT)

MACCRAT is a database maintained at HQMC. The data are compiled through individual squadron inputs of manpower numbers, including qualification, certifications, and licenses which are reported by MOSs within in the associated squadron. "[MACCRAT] is a lagging database which is compiled monthly and is a month behind, e.g., September's data are compiled the first of November" (J.D. Neal, personal communication, November 4, 2015). Data provided by MACCRAT for the present study have monthly observations for each squadron, from August 2012 to August 2015.

2. Variables, Data Cleaning, and Data Coding

The data sets retrieved from DECKPLATE and MACCRAT require several transformations before merging can occur. The data retrieved from MACCRAT is lagging, therefore the date associated with the reported observation is actually capturing the previous month. Each observation was modified to reflect the actual month when the observation occurred. The goal of this study was to find the effects of qualifications, regardless of MOS, on squadron readiness. Therefore, the data must be transformed to collapse the sum of qualifications regardless of MOS. This was done for the qualifications of CDI, CDQAR, and QAR. During the time the data were collected, the USMC was conducting a transition from HMH to VMM as well as HMLA squadrons upgrading form AH-1W to AH-1Z. These transitions affected the composition of squadrons and altered the data. There were instances when no qualifications were reported due to the infancy of the respective maintenance department's progress in transition. These instances were stricken from the data set. The MACCRAT data were also collapsed and summed by MOS. The sum of each MOS for each TMS is identical over time and aided in identifying squadrons that were composed of different TMS than what is considered normal. Since VMM squadrons are the reporting entities of the ACE, when deployed with other TMS, the sum of the MOSs will not equal the true VMM squadron MOS sum. Any VMM squadron whose sum of MOSs is not the true sum of a VMM is excluded from VMM binary variable and included in the Composite Squadron binary variable.

The DECKPLATE data set faced the same issue as the MCCRAT data set: the squadrons that were conducting a transition were not flying and, consequently, not reporting any readiness data. These anomalies where stricken from the dataset. The present study focuses on readiness metrics that are captured as a percentage. DECKPLATE offers the levels of readiness reported in equipment mission code hours (i.e., FMC, PMC, NMC, and MC). The process to account for this data transformation is seen in Figure 13, where Equipment In Service (EIS) hours represent the total amount of hours a squadron compiles in a month with aircraft that are in its custody.

Figure 13. Mission Code Calculation Formula

a. Total all related hours for each Mission Code, by TEC, and divide this sum by the total EIS hours for that equipment. The result is then multiplied by 100.

$$\text{AVG\%} = 100\ \frac{\text{(EQUIP MISSION CODE HRS)}}{\text{(EIS HRS)}}$$

Source: Commander, Naval Air Forces. (2012, May. 15). Naval Aviation Maintenance Program (NAMP) (4790.2B). San Diego, CA: Author

The dataset was collapsed and organized so that each squadron and date had observations for all of the readiness metrics, presented in percentages. To calculate the average number of aircraft a squadron is in custody of during a given Month, EIS is divided by the given hours in the month reported.

No common key between DECKPLATE and MACCRAT exists; however, one is required for a proper merge to take place. The squadron identifier (unit name) and the data associated with the observations are two unique variables shared between both data sets after the initial transformation of the date in the MACCRAT date. Combining these two variables provides a unique identifier and allows for a quality merge. In several instances, the MACCRAT MOS total did not correspond to the readiness data provided in DECKPLATE. The total EIS reported in these instances was a conglomeration of multiple TMS; however, the MOS sum was that of a true VMM. To account for this, any VMM squadrons reporting Aircraft over 18.5 (VMMT-204s maximum observed aircraft) were excluded from the VMM variable and included in the Composite Squadron variable. Seven more VMM squadrons remained after this transformation and were individually transformed from VMM to Composite Squadron. The end product of the merge yields a data set with 1,309 total observations. The distribution breakdown of the observations in relation to TMS can be seen in Table 9.

Table 9. Time-Series Number of Observations

Observations	HMLA	HMH	VMM	Composite Squadron	Total
	443	362	365	139	1309

The data did not include any form of RBA statistic, but provide enough information to create a variable that captures the feasibility of making RBA. The binary variable RBA was created based on the MC aircraft a squadron owns. Table 2 outlines specific parameters in the Marine Aviation Plan: 2015 dictates a squadron must possess to be RBA T-2.0 capable. The minimum MC aircraft for VMM, HLMA, and HMH are seven, sixteen, and eight, respectively. The maximum MC aircraft boundary is derived from the Primary Mission Aircraft Authorized (PMAA) for VMM, HLMA, and HMH;

they are twelve, twenty-seven, and sixteen, respectively. Any observation that fell between these two bounds is considered capable of attaining RBA. This variable does not account for aircraft in FCF status or those that are "L" coded.

3. Summary Statistics

The objective of the time series analysis is to determine the mathematical relationship between qualifications metrics and readiness metrics, as defined in Chapter II. We begin by analyzing the variability of qualifications, squadron size, and MC readiness metric. An understanding of the descriptive statistics in the data provides a basis for comparing different squadron types and offers evidence of correlations among variables. As seen in Table 10, the average MC of a squadron, regardless of TMS in custody of approximately 13 aircraft, is 56%. The composition of the qualifications CDI, CDQAR, and QAR averages approximately twenty-four, eighteen, and six, respectively. Table 10 does not capture the inherent differences in the squadron types. The mean, minimum, and max of qualification type do indicate that, for each TMS, the higher the level of qualification, the lower the amount available.

Table 10. Time-Series Aggregated Squadron Descriptive Statistics

Variable	n	Mean	S.D.	Min	25th Percentile	Median	75th Percentile	Max
CDI	1309	29.09	13.47	5.00	19.00	27.00	37.00	86.00
CDQAR	1309	21.57	11.33	1.00	13.00	19.00	29.00	74.00
QAR	1309	6.89	2.76	1.00	5.00	7.00	9.00	19.00
AIRCRAFT	1309	12.66	6.76	0.08	7.90	11.14	16.81	32.16
NMCS Hrs	1309	1038.98	722.42	0.00	501.00	878.00	1398.00	5045.00
MC	1309	0.56	0.16	0.00	0.46	0.57	0.67	1.00

As shown in Table 11, HMH squadrons have an average MC that is six percentage points lower than the aggregated average. In terms of qualifications, HMH averages are very similar to aggregated averages except for the CDQAR qualification, where, on average, there are five fewer than the aggregated. There is an indication of a robust supply posture due to the average hours spent awaiting parts being considerably lower than average aggregate NMCS Hrs. The average amount of aircraft for HMH squadrons is half of the HMH PMAA. The maximum amount of HMH aircraft is roughly what is required for PMAA.

Table 11. Time-Series HMH Descriptive Statistics

Variable	n	Mean	S.D.	Min	25th Percentile	Median	75th Percentile	Max
HMH CDI	362	27.93	10.83	5.00	22.00	28.00	34.00	53.00
HMH CDQAR	362	16.88	5.82	4.00	13.00	17.00	21.00	29.00
HMH QAR	362	7.33	2.57	1.00	6.00	7.00	9.00	14.00
HMH AIRCRAFT	362	8.77	3.76	0.08	5.68	8.85	11.57	18.36
HMH NMCS Hrs.	362	740.03	463.73	0.00	394.00	627.00	973.00	2769.00
HMH MC	362	0.50	0.17	0.00	0.38	0.50	0.64	1

VMM squadrons, depicted in Table 12, have an average MC that is two percentage points lower than the aggregated average. The average amount for each qualification is very low compared with the aggregated average and other squadrons. Even at the 75th percentile for VMM, qualifications are considerably lower than the aggregated average and other TMS alike. NMCS hours are also very low compared with the aggregated average and very similar to the HMH TMS. VMM average aircraft is the closest of all TMSs to its TMS PMAA.

Table 12. Time-Series VMM Descriptive Statistics

Variable	n	Mean	S.D.	Min	25th Percentile	Median	75th Percentile	Max
VMM CDI	365	21.24	5.41	8.00	18.00	21.00	24.00	39.00
VMM CDQAR	365	12.65	4.14	1.00	10.00	13.00	15.00	25.00
VMM QAR	365	4.41	0.93	2.00	4.00	4.00	5.00	8.00
VMM AIRCRAFT	365	9.98	3.52	0.33	8.40	10.19	11.86	18.55
VMM NMCS	365	773.05	422.25	0.00	459.00	740.00	1027.00	2274.00
VMM MC	365	0.54	0.15	0.00	0.44	0.53	0.63	1.00

Table 13 shows that HMLA squadrons have an average MC that is four percentage points higher than the aggregated average. The average amount of qualifications closely resembles the aggregated squadron average, except for the average amount of CDQARs. No other TMS than the HLMA has an amount of CDQARs that more closely resembles its amount of CDIs. On average, the HMLA has twelve less aircraft than the allotted PMAA and significantly more NMCS hours than any other TMS.

Table 13. Time-Series HMLA Descriptive Statistics

Variable	n	Mean	S.D.	Min	25th Percentile	Median	75th Percentile	Max
HMLA CDI	443	30.77	13.45	5.00	19.00	32.00	40.00	86.00
HMLA CDQAR	443	29.74	11.48	7.00	20.00	31.00	38.00	74.00
HMLA QAR	443	7.92	2.57	2.00	6.00	8.00	9.00	19.00
HMLA AIRCRAFT	443	14.65	6.79	0.14	8.00	15.00	19.35	32.16
HMLA NMCS	443	1231.64	780.14	0.00	656.00	1124.00	1650.00	5045.00
HMLA MC	443	0.60	0.13	0.22	0.51	0.61	0.69	1.00

Utilizing the created binary variable, RBA, we can capture the feasibility to attain RBA. A deployed unit has an Operational Status Category Code of "A." This indicates to the supply system that the unit has priority for receiving replacement parts (Commander, Naval Air Forces, 2012, Appendix E). Thus RBA, as with MC, can be greatly affected by deployment. RBA is presented in Table 14 and Table 15. Table 14 presents the feasibility of a squadron being RBA, not including observations during deployment. Table 15 includes the observations that were captured during the squadron's deployment.

Table 14. Time-Series RBA Not Including Deployed

RBA feasibility %	HMH/HMLA/VMM COMBINED	VMM	HMLA	HMH
Not RBA feasible	90.4	79.5	93.9	93.4
RBA feasible	9.6	20.5	6.1	6.6
Total	100	100	100	100

Table 15. Time-Series RBA Including Deployed

RBA feasibility %	HMH/HMLA/VMM COMBINED	VMM	HMLA	HMH
Not RBA feasible	88.3	78.9	91.6	89.2
RBA feasible	11.7	21.1	8.4	10.8
Total	100	100	100	100

The feasibility of attaining RBA for a VMM is more than double that of an HMLA or HMH, as shown in Table 14 and Table 15. Considering that the predominant factor in attaining the feasibility of RBA is MC aircraft, it makes sense that the VMM has a higher rate, because the mean aircraft for a VMM squadron is closer than any other TMS observed to the PMAA.

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V. MULTIVARIATE REGRESSION ANALYSIS AND SIMULATION MODEL

A. MULTIVARIATE REGRESSION ANALYSIS

1. The Multivariate Regression Analysis Method

This study utilizes Multivariate Linear Regression (MLR) to analyze the relationship between two variables by fitting a linear equation to observed data. An MLR uses several independent, explanatory variables that might explain variations in the dependent (outcome) variable.

Interpreting the results of an MLR is broken down into three categories: the significance, sign, and magnitude of coefficient. Significance in an MLR is based on the p value of the explanatory variables. A p value that falls within the thresholds of significance (.01, .05, .1) indicates that the explanatory variable has an effect on the dependent variable. The sign indicates whether the explanatory variable has a positive effect or negative effect on the dependent variable. The magnitude of an explanatory variable coefficient is the effect that a one-unit increase in that particular variable has on the dependent variable, holding all other explanatory variables constant. ("About MLR," n.d.).

2. Multivariate Analysis of the Relation between Qualifications and Aviation Readiness, Measured by RBA

To examine the relation between Marine aviation maintainer qualifications and aviation readiness, we assume that readiness is a function of qualifications, aptitude (as indicated by AFQT score), rank, years of service, marital status, and NMCS hours, among other factors. Given our data limitations, we are restricted to using our cross-sectional data set, which shows a snapshot in time of existing personnel qualifications and reported readiness, as measured by percentage RBA.

The regression model is as follows.

$$Y = \beta_0 + \beta_1 X_{1,q} + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \varepsilon$$

Where
Y = readiness percentage, RBA
$X_{1,q}$ = count of qualifications
X_2 = count of NCO's
X_3 = AFQT test score
X_4 = marital status
X_5 = race, white
X_6 = years of service
X_7 = hours of NMCS
ε = residual
q = qualification type

The estimated coefficients showed relatively weak results, only able to predict two of the four qualification levels with any level of significance, as shown in Table 16. The two most significant qualifications of interest are CDI and CDQAR, having a slightly negative effect and slightly positive effect, respectively, on RBA. Although these results have 95% significance, the model as a whole only describes 35% of the variation in RBA, as shown by the R-squared. NMCS was shown to be very significant, with 99% confidence, and it has a negative effect on RBA, as one would reasonably expect.

The data behind this regression model are useful in describing the population features, but they do not describe the effect on RBA very well. The data include almost 3,000 observations, but only 38 exclusive squadron RBA percentages were used as the dependent variable. This problem was caused because only one snapshot date of qualifications was available due to ASM limitations. The results of this model are fairly inconclusive and more than likely due to the data lacking the element of time, essentially aggregating 2,966 observations into 38. Although the cross-sectional RBA regression models are included in this thesis, the findings are inconclusive. The time-series regression will prove to be much more successful in describing the effect of qualifications on readiness, although readiness measured in MC as opposed to RBA.

The next cross-sectional regression model seeks to describe the relation between individual Marine's characteristics and qualifications. To examine the relation between human characteristics and qualifications, we assume that qualifications are a function of rank, years of service, aptitude (AFQT score), marital status, race, and squadron type, among other factors.

$$Y_q = \beta_0 + \beta_1 X_{1,q} + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \varepsilon$$

Where

Y_q = qualification type

$X_{1,q}$ = typical rank for qualification

X_2 = years of service

X_3 = AFQT test score

X_4 = marital status

X_5 = race, white

$X_{6,s}$ = squadron type

ε = residual

q = qualification type

s = squadron type

Table 16. Cross-Sectional All Squadron Qualifications Regression on RBA

VARIABLES	**< CDI** **RBAP**	**CDI** **RBAP**	**CDQAR** **RBAP**	**QAR** **RBAP**
< CDI	0.0056			
	(0.0037)			
NCO	-0.0039	-0.0041	-0.0066**	-0.0059*
	(0.0033)	(0.0032)	(0.0032)	(0.0031)
AFQT_SCORE	-0.0001	-0.0001	-0.0001	-0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Married	-0.0032	-0.0035	-0.0041	-0.0035
	(0.0033)	(0.0032)	(0.0033)	(0.0032)
White	0.0016	0.0015	0.0014	0.0016
	(0.0041)	(0.0041)	(0.0041)	(0.0041)
YOS	0.0005	0.0001	-0.0001	0.0005
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
NMCS	-0.7280***	-0.7281***	-0.7287***	-0.7287***
	(0.0183)	(0.0183)	(0.0183)	(0.0183)
CDI		-0.0071**		
		(0.0036)		
CDQAR			0.0088**	
			(0.0043)	
QAR				-0.0095*
				(0.0051)
Constant	0.6675***	0.6744***	0.6747***	0.6728***
	(0.0104)	(0.0096)	(0.0096)	(0.0096)
Observations	2,966	2,966	2,966	2,966
R-squared	0.3510	0.3513	0.3514	0.3512

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

3. Multivariate Analysis of the Relation between Individual Characteristics and Qualifications

The model shown in Table 17 seeks to describe the individual's characteristics, both demographic and professional, and being a CDI. This model's estimates suggest that maintainers have a higher chance of being a CDI if they are a corporal, are married, or from the HMLA/VMM community, with 99% significance. Corporal was selected as the rank independent variable of interest because CDI is a junior qualification and corporal is the junior rank of the NCOs. Corporal was included as the "typical" rank independent variable of a CDI. Being a corporal gives a maintainer a 10% higher likelihood of being a CDI according to the model. Years of service was selected due to its suspected positive effect on being a CDI, but was shown to be insignificant. This is likely the case because CDI is a fairly junior qualification, not having much to do with years of service as opposed to the higher qualifications. Being married had a significant positive effect on being a CDI. A married maintainer has a 4% higher likelihood of being a CDI as compared with a non-married maintainer. This may be due to married Marines seeking out additional responsibility to build a career for their family or due to a perception from leadership who are driving qualification advancement that married Marines are more mature. An unexpected significant observation was made that being in an HMLA decreased a maintainer's likelihood of being a CDI by 6%, while being a VMM increases it by 5%. This effect will reverse itself with the advancement of qualification in every squadron type, possibly displaying a form of equilibrium across squadron types.

The regression model shown in Table 18 seeks to describe the relationship between the individual's maintainer's characteristics and being a CDQAR. This model suggests that maintainers have a higher chance of being a CDQAR if they are sergeant or if they have more years of service. This model still shows a positive effect if they are married, but the effect is less significant and less amplified than in the CDI model. Similar to above, sergeant was selected as the rank independent variable of interest because CDQAR is a mid-level qualification and sergeant is the "typical" CDQAR rank. Being a sergeant gives a maintainer a 23% higher likelihood of being a CDQAR. Variable "Years of service" was again selected due to its suspected positive effect on being a CDQAR, and was now shown to be significant. This is likely because CDQAR requires a significant amount of experience, often the case with more years of service. The squadron types were significant and had opposite effects as the CDI model, again possibly due to some form of qualification equilibrium demanded by the different squadron types.

Table 17. Individual Characteristics and CDI, using Cross-Sectional Data Set

VARIABLES	**(1) CDI**	**(2) CDI**	**(3) CDI**	**(4) CDI**
Cpl	0.0973***	0.0981***	0.0975***	0.0963***
	(0.0174)	(0.0174)	(0.0173)	(0.0174)
YOS	0.0013	0.0015	0.0015	0.0012
	(0.0019)	(0.0019)	(0.0019)	(0.0019)
AFQT_SCORE	0.0001	0.0001	0.0001	0.0001
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Married	0.0442***	0.0435***	0.0420**	0.0437***
	(0.0166)	(0.0166)	(0.0165)	(0.0166)
White	0.0058	0.0059	0.0064	0.0060
	(0.0213)	(0.0213)	(0.0213)	(0.0213)
HMH		0.0296*		
		(0.0164)		
HMLA			-0.0637***	
			(0.0153)	
VMM				0.0458***
				(0.0169)
Constant	0.1463***	0.1360***	0.1708***	0.1341***
	(0.0413)	(0.0417)	(0.0416)	(0.0415)
Observations	2,966	2,966	2,966	2,966
R-squared	0.0129	0.0140	0.0186	0.0153

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 18. Individual Characteristics and CDQAR, using Cross-Sectional Data Set

	(1)	(2)	(3)	(4)
VARIABLES	**CDQAR**	**CDQAR**	**CDQAR**	**CDQAR**
Sgt	0.2336***	0.2375***	0.2300***	0.2289***
	(0.0140)	(0.0139)	(0.0138)	(0.0140)
YOS	0.0148***	0.0144***	0.0144***	0.0148***
	(0.0015)	(0.0015)	(0.0015)	(0.0015)
AFQT_SCORE	0.0002	0.0002	0.0001	0.0002
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Married	0.0331**	0.0341**	0.0372***	0.0344**
	(0.0135)	(0.0134)	(0.0134)	(0.0135)
White	0.0127	0.0124	0.0117	0.0124
	(0.0171)	(0.0170)	(0.0169)	(0.0171)
HMH		-0.0660***		
		(0.0131)		
HMLA			0.0984***	
			(0.0122)	
VMM				-0.0498***
				(0.0136)
Constant	-0.0405	-0.0188	-0.0780**	-0.0261
	(0.0327)	(0.0328)	(0.0326)	(0.0328)
Observations	2,966	2,966	2,966	2,966
R-squared	0.1368	0.1441	0.1555	0.1407

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The model shown in Table 19 seeks to describe the relationship between the individual maintainer's characteristics and being a QAR. This model suggests that maintainers have a higher chance of being a QAR if they are the typical QAR rank of staff sergeant or from having more years of service. The type of helicopter squadron again reversed its significant effect in this model. Staff sergeant was selected as the rank independent variable of interest because the NAMP recommended that QARs be SNCOs. Being a staff sergeant gives a maintainer 6 percentage points higher likelihood of being a QAR. Years of service was again selected due to its suspected positive effect on being a QAR, and was shown to be significant. Each additional year of service provides a maintainer with a 4 percentage point higher chance of being a QAR. This is again likely because QAR requires a significant amount of experience, again correlated with years of service.

Table 19. Individual Characteristics and QAR, using Cross-Sectional Data Set

VARIABLES	(1) QAR	(2) QAR	(3) QAR	(4) QAR
SSgt	0.0636***	0.0599***	0.0614***	0.0637***
	(0.0189)	(0.0189)	(0.0188)	(0.0189)
YOS	0.0410***	0.0413***	0.0412***	0.0410***
	(0.0015)	(0.0015)	(0.0015)	(0.0015)
AFQT_SCORE	0.0003	0.0003	0.0003	0.0003
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Married	-0.0038	-0.0046	-0.0050	-0.0039
	(0.0115)	(0.0115)	(0.0115)	(0.0115)
White	0.0234	0.0236	0.0237	0.0235
	(0.0148)	(0.0148)	(0.0148)	(0.0148)
HMH		0.0345***		
		(0.0114)		
HMLA			-0.0333***	
			(0.0106)	
VMM				0.0038
				(0.0117)
Constant	-0.1424***	-0.1543***	-0.1297***	-0.1434***
	(0.0283)	(0.0285)	(0.0285)	(0.0284)
Observations	2,966	2,966	2,966	2,966
R-squared	0.3120	0.3141	0.3143	0.3120

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

It is important to note that each of these three regression models, relating individual Marine’s characteristics on qualifications, only provides 13–35% explanation of the dependent variables. The low R-squared suggests that there are other unknown significant factors that were not included in these models. Other interesting results point out that, although 85% of the population is white, it has no significance on qualifications in any regression, and neither does AFQT score. Having a marital status of “married” has a positive correlation with CDI, yet it loses its statistical significance beyond CDI. The waffling effect on squadron type as qualifications advance is surprising, although could realistically be explained by the different advancement cultures to which each squadron type conforms. Given the data limitations, we caution the reader to take the findings presented in this section as preliminary. A more robust analysis requires better data and, hence, better econometric modeling, currently not feasible.

4. Multivariate Analysis of the Relation between Qualifications and Aviation Readiness, Measured by MC

Multivariate analysis using the time series data set is able to generate a much stronger result due to more information contained in the dataset we were able to compile. The goal of the model is to capture a more accurate measure of the effect of maintainer qualifications on readiness, specifically MC. Since MC is predominantly derived from maintenance action and supply availability, it is necessary to account for the effect of supply shortfalls on MC. This is accomplished by including the NMCS hours variable. Deployment also affects squadron's mission readiness. As previously stated, a unit that is deployed has a higher priority for logistical support than do non-deployed units. This is accounted for by including the deployment binary variable. We have not delineated the different squadron types in the initial model. Each qualification is analyzed independently to capture the effect of each qualification on MC, while account for collinearity. We formulate the linear regression model as follows:

$$Y_{t,q} = \beta_0 + \beta_1 X_{1,t,q} + \beta_2 X_{2,t,q} + \beta_3 X_{3,t,q} + \beta_4 X_{4,t,q} + \varepsilon$$

Where

$Y_{t,q}$ = readiness percentage MC

$X_{1,t,q}$ = total qualifications

$X_{2,t,q}$ = total planes

$X_{3,t,q}$ = NMCS hours

$X_{4,t,q}$ = deployed

$\varepsilon_{t,q}$ = residual

t = month year

q = qualification type

The estimates from this regression model are shown in Table 20.

Table 20. All Squadron Qualifications Regression on MC, using Time Series Data

	(1)	**(2)**	**(3)**
VARIABLES	**MCP**	**MCP**	**MCP**
CDI	0.000413		
	(0.000396)		
NMCSHrs	-0.000123***	-0.000124***	-0.000122***
	(8.36e-06)	(8.22e-06)	(8.38e-06)
Deployed	0.0494***	0.0556***	0.0509***
	(0.0103)	(0.0101)	(0.0102)
Planes	0.0128***	0.00989***	0.0134***
	(0.00103)	(0.00105)	(0.000962)
CDQAR		0.00296***	
		(0.000471)	
QAR			-0.000976
			(0.00164)
Constant	0.505***	0.490***	0.515***
	(0.00960)	(0.00879)	(0.0109)
Observations	1,309	1,309	1,309
R-squared	0.196	0.219	0.195

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This model's ability to better explain the variation in readiness is indicated by the R-squared values, at about 20 percent. We also see that not all variables are statistically correlated with MC. This is indicated by the p value. The only qualification of interest that is significant is the CDQAR, which indicates that the increase of CDQAR by one will generate a .3 percentage point increase in MC, holding all else constant.

We determine that it is necessary to control for the squadron type when regressing the effects of qualifications on MC. Each Squadron operates on different aircraft and with different MOSs. We control for this by adding a squadron term. This process allows us to identify the explanatory potency of each squadron type. We formulate the linear regression model below.

$$Y_{s,t,q} = \beta_0 + \beta_1 X_{1,s,t,q} + \beta_2 X_{2,s,t,q} + \beta_3 X_{3,s,t,q} + \beta_4 X_{4,s,t,q} + \varepsilon$$

Where
$Y_{s,t,q}$ = readiness percentage MC
$X_{1,s,t,q}$ = total qualifications
$X_{2,s,t,q}$ = total planes
$X_{3,s,t,q}$ = NMCS hours
$X_{4,s,t,q}$ = deployed
$\varepsilon_{s,t,q}$ = residual
s = squadron type
t = month year
q = qualification type

The HMH squadron model is able to explain roughly 77 percent of the variation in MC, as seen in Table 21. We also see that each of the qualifications is significantly correlated with MC, while being deployed is insignificant at the 95th percentile. An increase of CDI by one takes on a .9 percentage point increase in MC; one additional CDQAR takes on a 2.3 percentage point increase in MC; and one additional QAR takes on a 3.5 percentage point increase in MC, ceteris paribus. The model also produces positive coefficients for planes for each HMH qualification across the board, indicating that the addition of planes would positively affect the MC in a squadron. This makes sense due to the fact that the divisor in the MC percentage increases when adding aircraft. We also see a significant negative coefficient for NMCS hours. The magnitude that the coefficient takes on is quite low; however, in terms of hours per month, it has a large impact. Considering the average monthly NMCS hours HMH squadron has is 740, this would translate to a degradation between 8.5 and 13 percent among the qualifications.

Table 21. All HMH Squadron Qualifications Regression on MC, using Time Series Data

	(1)	(2)	(3)
VARIABLES	**HMHMCP**	**HMHMCP**	**HMHMCP**
HMHCDI	0.00918***		
	(0.000566)		
HMHPLANES	0.0297***	0.0232***	0.0344***
	(0.00224)	(0.00211)	(0.00207)
HMH_NMCS	-0.000116***	-0.000136***	-0.000173***
	(1.61e-05)	(1.52e-05)	(1.64e-05)
Deployed	0.00826	0.0150*	0.0147*
	(0.00826)	(0.00780)	(0.00833)
HMHCDQAR		0.0201***	
		(0.000939)	
HMHQAR			0.0354***
			(0.00225)
Constant	0.0182***	0.0135***	0.0162***
	(0.00424)	(0.00402)	(0.00429)
Observations	1,309	1,309	1,309
R-squared	0.761	0.787	0.758

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

We find very similar results in the HMLA model estimates, seen in Table 22. Notable differences are the magnitudes of the coefficients of the qualifications. We see that the effect of CDI and QAR is slightly higher for an HMLA than an HMH. We also see that deployment is a significant contributor to the model for CDQAR and QAR and has a positive magnitude. This shows evidence that, while an HMLA squadron is deployed, they have an increase in MC percentage.

Table 22. All HMLA Squadron Qualifications Regression on MC, using Time Series Data

VARIABLES	(1) HMLAMCP	(2) HMLAMCP	(3) HMLAMCP
HMLACDI	0.0105***		
	(0.000659)		
HMLAPLANES	0.0209***	0.0154***	0.0149***
	(0.00171)	(0.00170)	(0.00136)
HMLA_NMCS	-0.000118***	-9.99e-05***	-0.000111***
	(1.37e-05)	(1.31e-05)	(1.16e-05)
Deployed	0.0120	0.0208**	0.0367***
	(0.0104)	(0.0100)	(0.00892)
HMLACDQAR		0.0134***	
		(0.000675)	
HMLAQAR			0.0568***
			(0.00195)
Constant	0.0386***	0.0314***	0.0172***
	(0.00552)	(0.00533)	(0.00479)
Observations	1,309	1,309	1,309
R-squared	0.750	0.771	0.819

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The estimates for the VMM model are shown Table 23, indicating that qualifications have a more pronounced positive effect on MC percentage than any other squadron type examined in this analysis. We also note that the VMM model explains the most variability of residuals than do HMH and HMLA, as well. The coefficients of NMCS hours also indicate that the supply systems deficiencies do not effect the VMM as much as other squadrons observed in this study. Also, the number of planes that a VMM squadron has does not effect the MC percentage as much as the HMH and HMLA squadrons.

Table 23. All VMM Squadron Qualifications Regression on MC, using Time Series Data

	(1)	(2)	(3)
VARIABLES	**VMMMCP**	**VMMMCP**	**VMMMCP**
VMMCDI	0.0185***		
	(0.000532)		
VMMPLANES	0.0177***	0.0166***	0.0199***
	(0.00152)	(0.00174)	(0.00161)
VMM_NMCS	-7.12e-05***	-2.96e-05**	-0.000116***
	(1.31e-05)	(1.43e-05)	(1.38e-05)
Deployed	-0.0142**	-0.00552	-0.00256
	(0.00629)	(0.00672)	(0.00660)
VMMCDQAR		0.0283***	
		(0.000958)	
VMMQAR			0.0915***
			(0.00297)
Constant	0.0103***	0.0120***	0.00830**
	(0.00324)	(0.00347)	(0.00343)
Observations	1,309	1,309	1,309
R-squared	0.877	0.858	0.863

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

B. SENSITIVITY ANALYSIS USING MONTE CARLO SIMULATION

1. Simulation foundation

Sensitivity analysis was performed using a regression calculator and Crystal Ball Monte Carlo simulation software. The regression calculator was used to determine a single predicted value when the independent variables could be given. A second regression calculator was also built to measure the qualifications it would take to achieve a given MC percentage. To add depth, this study was able to simulate a distribution of values to build a reasonable amount of variation around the dependent and independent variables that the calculator predicted. This type of sensitivity analysis was used to analyze feasibility to meet changes in MC percentage and number of planes.

a. Regression Calculator

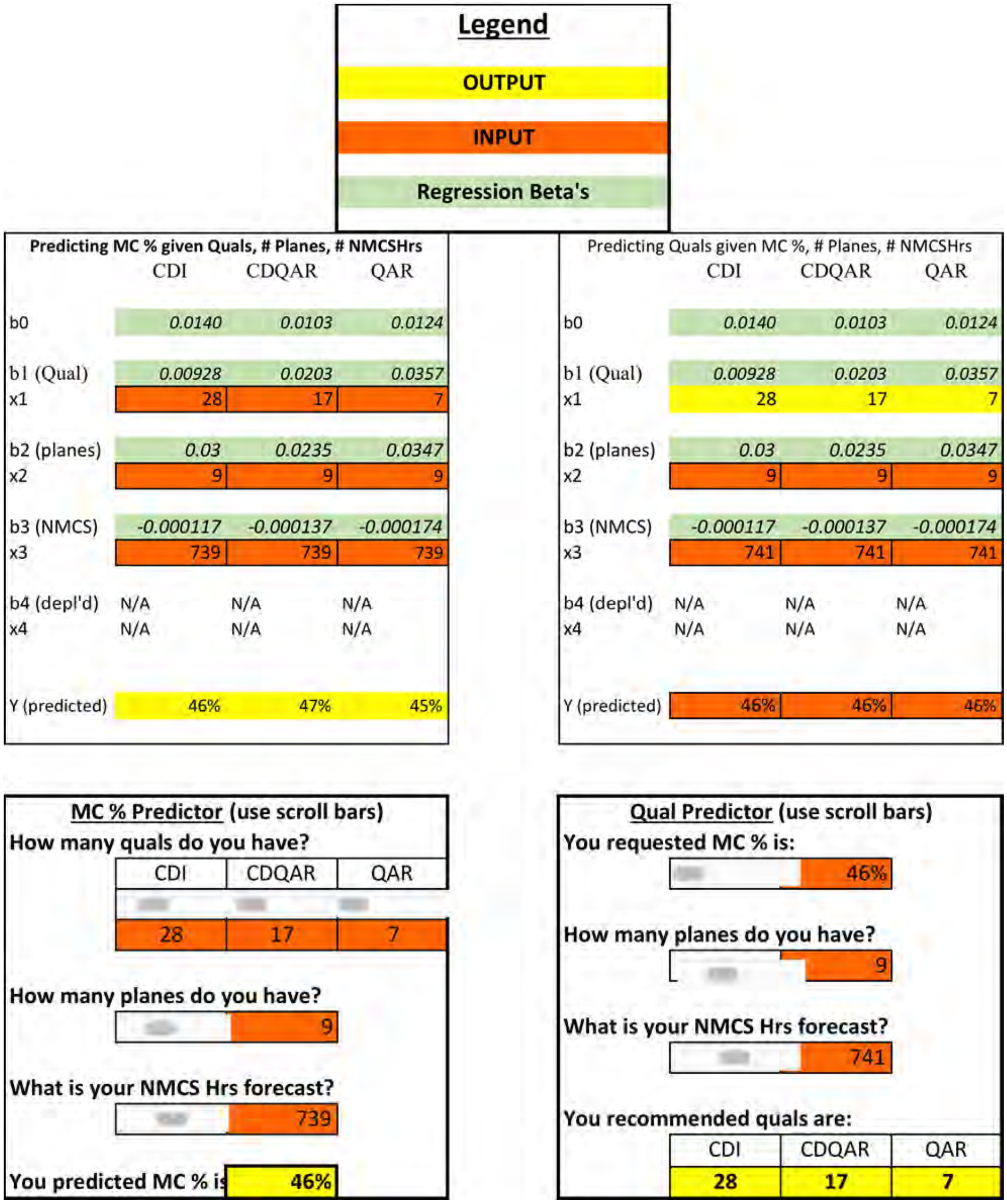
A regression calculator for each squadron type, as shown in Figure 14, was used to predict the MC percentage based on the results from each time-series regression. A reverse model was also built using the same regression results to calculate various levels of qualifications from an MC percentage. Due to each regression being independent, three regressions each predicted their own MC. The prediction calculator took a simple average of these regression predictions to develop the average MC prediction across the three models. The qualification predictor (reverse model) used the same regression models to provide the proper number of qualifications when given all other variables, including the MC. This calculator can function as follows: if a squadron knows what their current MC percentage is, they can change their expected MC percentage to see how many qualifications it would take to affect that new MC percentage. Any flaws that are inherent to the regression, such as missing the error term, are also inherent to this calculator.

Despite the unknown error term present in the regressions causing some form of bias, variation can be injected into these regressions to provide a range of possibilities as opposed to a single number. Variation is what the Monte Carlo simulation seeks to add to the model to provide a range of predictions for both MC percentage and qualifications needed to achieve a given MC percentage.

b. Underlying Distribution Assumptions

To provide variation, the type of variation should first be understood. Crystal Ball Monte Carlo software is able to analyze the same data used to build the regressions, which serves to provide a recommended distribution for each data field. Each data field was first inputted into a histogram by the software to determine its distribution shape. (See Appendix: Simulations, Figure 15, Figure 20, and Figure 25, which illustrates the distribution types and parameters that were selected for each regression that was simulated.) The parameters used were calculated from the data. Selecting the proper distribution type allows the simulation to provide the correct amount of variation as it runs to provide a proper forecast.

Figure 14. HMH Regression Calculator



2. MC regression model simulated

MC percentage was simulated 10,000 times for each squadron type and qualification in crystal ball using the underlying distributions, as mentioned above. (See Appendix: Simulations, Figure 16, Figure 21, and Figure 26 for the MC percentage results from the HMH, HMLA, and VMM regressions, respectively.) Each of the simulations provided slightly different, although similar, results, which used the CDI, CDQAR, and QAR regression models. Generally, the simulation mean outputs aligned closely with what each regression predicted.

The biggest significance of the MC simulations is from comparing simulated regression results to the MC goal of 73%. The HMH MC models in Figure 16 suggest that, at their status quo of 28 CDIs, 13 CDQARs, 4 QARs, 9 aircraft, and 740 NMCS hours, the MC goal of 73% will only be met between 4–6% of the time. The HMLA MC models in Figure 21 suggest that, at their status quo of 31 CDIs, 30 CDQARs, 8 QARs, 15 aircraft, and 1232 NMCS hours, the MC goal of 73% will only be met between 19 - 36% of the time. The VMM MC models in Figure 26 suggest that, at their status quo of 21 CDIs, 13 CDQARs, 4 QARs, 10 aircraft, and 773 NMCS hours, the MC goal of 73% will only be met between 8–24% of the time.

3. Qualifications Simulated from Regression

Being able to predict the necessary qualifications when given the remaining terms of the equation could provide the ability to plan for qualifications needed. This section describes the effect on needed qualifications when a squadron chooses to increase its MC percentage or if they receive a few more aircraft (planes).

a. Recommended Qualifications at Average State

Figure 17, Figure 22, and Figure 27 display the recommended qualifications when a squadron is at its average state (status quo) regarding MC percentage, number of aircraft, and number of NMCS hours. For example, Figure 17 illustrates that 32 CDIs will be needed for an HMH to meet 50% MC. Figure 17 also suggests that 53 CDIs are necessary to meet a 50 percent MC rate, 90 percent of the time. Another simple way of interpreting these results is that, in order to increase MC above 50 percent, the squadron should have more than 32 CDIs. In an average HMH setting, the simulation suggests 32 CDIs, 18 CDQARs, and 8 QARs are needed. Another valuable application of this simulation is to observe the change of suggested qualifications when the MC percentage is boosted 10% higher.

b. Recommended Qualifications at 10% Higher MC

This discussion references Figure 18, Figure 23, and Figure 28, which provide a suggested breakdown of qualifications when the only change from the last model is a 10% increase in MC. As shown in Figure 23, the simulation suggests that, for an average HMLA to increase MC by 10%, it should increase its number of CDIs from 38 to 46, increase its CDQARs from 35 to 41, and increase its QARs from 9 to 11. Another way of looking at this is by adding 8 CDIs, 6 CDQARs, and 2 QARs to increase MC by 10%.

c. Recommended Qualifications with More Planes

The authors were also curious to explore the effects of added aircraft from an average state. These results are shown in Figure 19, Figure 24, and Figure 29, but were negligible. The simulation predicted an HMH going from 9 to 11 aircraft, an HMLA from 15 to 20, and a VMM from 10 to 12. In each of these cases, the simulation did not indicate any change in any number of qualifications.

d. Recommended Qualifications at MC Goal of 73%

As previously discussed, the NAMP lists the CNO's MC goal of 73% (Commander, Naval Air Forces, 2012). The 2015 Marine Aviation Plan also refers to this goal saying, "achieve the Commandant's readiness goals for MC/FMC rates as specified in COMNAVAIRFORINST 4790.2B, Chapter 17.2.1" (Headquarters Marine Corps, 2014, p. 2.8.6). This 73% MC goal was simulated given an average number of planes and NMCS hours to see what qualification goals the simulation would recommend, as depicted in Figure 30, Figure 31, and Figure 32. These figures display how many average qualifications it would take to meet the 73% goal, on average, and how many it would take to meet the same goal only 10% or 90% of the time.

Figure 30 illustrates a recommendation of 46 CDIs, 26 CDQARs, and 12 QARs to meet the stated MC goal on average for an HMH. This is an increase of 14 CDIs, 8 CDQARs, and 2 QARs. Figure 31 depicts a recommendation of 49 CDIs, 43 CDQARs, and 11 QARs to meet the stated MC goal, on average, for an HMLA. This is an increase of 11 CDIs, 8 CDQARs, and 2 QARs. Figure 32 is shown to suggest a recommendation of 31 CDIs, 20 CDQARs, and 6 QARs to meet the stated MC goal, on average, for a VMM. This is an increase of 4 CDIs, 3 CDQARs, and 1 QARs.

4. Simulation Summary

The Monte Carlo simulations provide a range of values when combined with the regression model, which is more characteristic of reality than a simple calculated result. The simulation results loosely resemble the actual data provided, although not exactly. Tools such as this could be utilized in future planning of maintenance manpower staffing. Table 24 is shown to suggest the recommended number of qualifications to add when considering an added 10% MC or an increase to 73% MC from average. Adding 2 planes for an HMM/VMM or 5 planes to an HMLA proved to have a negligible requirement of any added qualifications across the board.

Table 24. Recommended Qualification Changes from Simulation Results

Recommended Qualifications from Simulation				
		HMH		
		Recommended added quals from average		
	Average # of Quals	2 Added Planes	(+) 10% MC	73% MC
CDI	32	0	7	14
CDQAR	18	0	4	8
QAR	8	0	2	4

		HMLA		
		Recommended added quals from average		
	Average # of Quals	5 Added Planes	(+) 10% MC	73% MC
CDI	38	0	8	11
CDQAR	35	0	6	8
QAR	9	0	2	2

		VMM		
		Recommended added quals from average		
	Average # of Quals	2 Added Planes	(+) 10% MC	73% MC
CDI	22	0	5	9
CDQAR	14	0	3	6
QAR	4	0	1	2

C. DISCUSSION OF RESULTS

The estimates using the cross-sectional data set are not robust enough to describe the effect of qualifications on RBA readiness due to their lack of including a time dimension. However, the cross-sectional database provides inference into what individual maintainer characteristics are most likely related to aviation maintenance qualifications. The cross-sectional results suggest that having the “typical” rank of a particular qualification has a significant positive effect. Additionally, being married has significant impact on being a CDI. While the married effect does not continue for more advanced qualifications, years of service does have an increasing effect along with the typical rank. This model does not describe readiness as well as the authors had hoped, but it does describe some characteristics that drive qualifications.

The estimates using time series data add the dimension lacking in the cross-sectional data and provide substantial evidence that qualifications have a positive effect on MC readiness. The advancement of qualifications in a USMC squadron is a linear progression. We see that at each level of qualification, as the magnitude of the positive coefficient increases from the last. We also find that increasing the amount of aircraft in each squadron universally increases the MC percentage. The present study also finds evidence that the increase in NMCS hours affects the MC percentage negatively. While the risk for reverse causality exists by including these two variables, we consider the omitted variable bias that would be present from their exclusion to outweigh its effects.

The sensitivity analysis, obtained through Monte Carlo simulation, provided insight into how often an average squadron can meet the readiness standard, which is seemingly low. The simulations also were used to suggest changes in the squadron qualification structures based on adding MC percentage and even meeting the MC goal of 73%. This study was able to determine a measure of the effect of qualifications on readiness and the effects of human characteristics on qualifications.

VI. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

Aircraft readiness is a critical factor in Marine Corps aviation mission success. State-of-the-art systems and platforms are insignificant if they are inoperable. This thesis finds that both the supply system and the amount of qualifications have a dramatic effect on the level of readiness individual squadrons can achieve. The Marine Corps can increase the number of qualifications more easily than it can change the supply system. This thesis uses heavy, light/attack, and tiltrotor Marine squadron data to analyze the effect that qualifications have on aircraft readiness. Qualifications that form the focus of the study are CDI, CDQAR, and QAR. Each qualification level is also examined from a human characteristics perspective to determine the demographics that are correlated with each qualification level.

We find that qualifications have a significant effect on the readiness of Marine Corps squadrons. Each platform examined shows a positive response with the addition of qualifications. As the level of qualification grows, the magnitude of increased readiness also rises, indicating that a higher level of qualification has the most pronounced effect on readiness. We also simulated these effects using Monte Carlo simulation, creating a proof-of-concept for our regression model that illustrates the probability of achieving MC percentages. Additionally, the simulations were used to suggest the qualification composition of a squadron when given the remaining factors. The simulations suggest that a small increase in the number of qualifications, as shown in Table 24 (Chapter V), would result in squadrons meeting the CNO’s MC goal of 73%.

B. CONCLUSIONS

To formulate our conclusions, we focus on the scope of our study, as summarized by the research questions presented in Chapter I.

1. Primary Research Question

- What is the effect of USMC enlisted aviation maintenance qualifications on squadron aviation readiness?

Using multivariate analysis and both a cross-sectional and time-series data set, the overall findings show enlisted aviation maintenance qualifications have a positive effect on aircraft readiness in the HMH, HMLA, and VMM squadrons. The authors speculate this is due to the direct and frequent interaction that these qualified Marines have with the aircraft, creating the foundation of aviation readiness by providing flyable aircraft to the aircrews.

2. Secondary Research Questions

- Do other factors—such as pay grade/rate, marital status, family size, race, duty station, and test scores—affect enlisted qualifications in aviation maintenance?

Factors found to have a significant and positive effect on qualifications are rank, marital status, and squadron type. Race and test scores did not correlate significantly with qualifications. The most significant positive factor is rank, with an effect that increases as qualifications become more advanced. The authors believe that rank is closely related to experience, and any variable indicative of added experience will also correlate with higher qualifications.

- Does each successive reenlistment affect qualifications?

Because qualifications are a linear progression, it takes time for an individual Marine to ascend the qualification ranks. The amount of time for a Marine to achieve the qualification CDQAR is roughly five years. Five additional years are required for that Marine to achieve QAR. This observation is captured in Figure 11 (Chapter IV). As qualification level increases, fewer Marines meet the qualifications. This pattern is paralleled by the rank structure in the Marine Corps, which is a product of reenlistment. Since reenlistment is not directly tied to maintenance qualifications, there is no guarantee that the most qualified Marines (in maintenance terms) are granted reenlistment. Additionally, since reenlistment is voluntary, some of the best-qualified Marines are also highly valuable and will self-select to the civilian marketplace. This scenario has the ability to degrade squadron readiness.

- What type of qualification structure should a squadron have when given an expected level of readiness?

Table 24 (Chapter V) depicts the recommended squadron qualification structure for three different Marine Corps scenarios and an added aircraft scenario. These qualification recommendations are not overly burdensome, as supported by the data we analyzed, and are likely to improve squadron readiness percentages.

C. RECOMMENDATIONS

1. Recommended Changes

Just as any business seeks to align its workforce with its strategic goal, Marine aviation can align its manpower strategy with its strategic goal of readiness. Aviation readiness is comprised of several elements, but starts with the foundation of aircraft readiness. The current method of reenlistment or reassignment does not formally consider maintenance qualifications. We recommend that maintenance qualifications be directly considered for reenlistment or reassignment.

It would be wise for future manpower policies to consider incentivizing qualifications, as they have been shown to increase the end-goal of readiness. Just as it is common knowledge to build one's house on a strong foundation, Marine aviation should invest in a stronger foundation by including qualifications in decisions when shaping the maintenance force. Qualifications with the largest effect on readiness are those that require more time served. Directly mandating that Marines attain and maintain qualifications to reenlist is a plausible option.

This study indicates that, to some degree, qualifications affect readiness, and they should be taken into account when making staffing decisions. It is understood that rank must also be considered in assignments, suggesting that a combination of factors that includes rank and qualifications could be developed to boost aviation readiness. Further, the legacy SRB system could include a modified approach that properly incentivizes needed qualifications in addition to rank.

2. Areas for Further Study

Data limitations in the present study did not allow for a full assessment of the relation between Marines' qualifications and aviation readiness. For example, cross-sectional data were limited due to the lack of a time element in ASM. Although ASM has no need to archive its own data, MACCRAT will be archiving ASM data in the near future. The cross-sectional model could be observed repeatedly, over time, with the added time-series element of ASM from MACCRAT, allowing researchers to build a very robust data set. This would greatly improve the strength of the analysis. As RBA becomes more prevalent as the aircraft readiness standard of choice across all databases, analyzing it should become easier.

Retention analysis of this same target population is another topic that should be ripe for exploration once ASM begins to become archived. If one could quantify the financial value of a maintenance qualification, then a cost-benefit analysis could be performed to determine the optimal bonus needed to retain these Marines versus replacement cost. As military policy makers continue to model personnel retention strategies on civilian-type methods, incentivizing qualifications as human capital could become the way of the future.

APPENDIX: SIMULATIONS

Figure 15. HMH Underlying Distributions

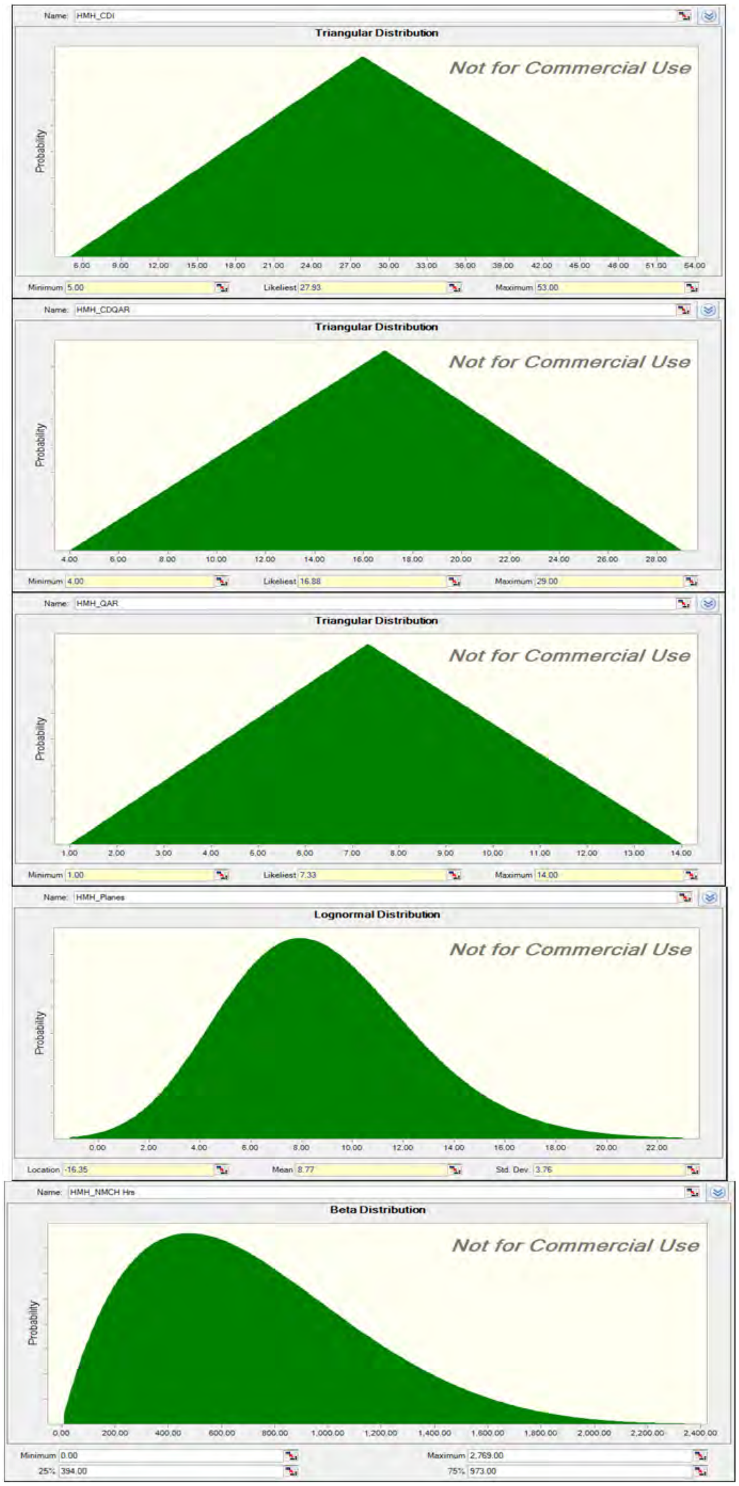


Figure 16. HMH Regressions, MC % Simulated at Average States

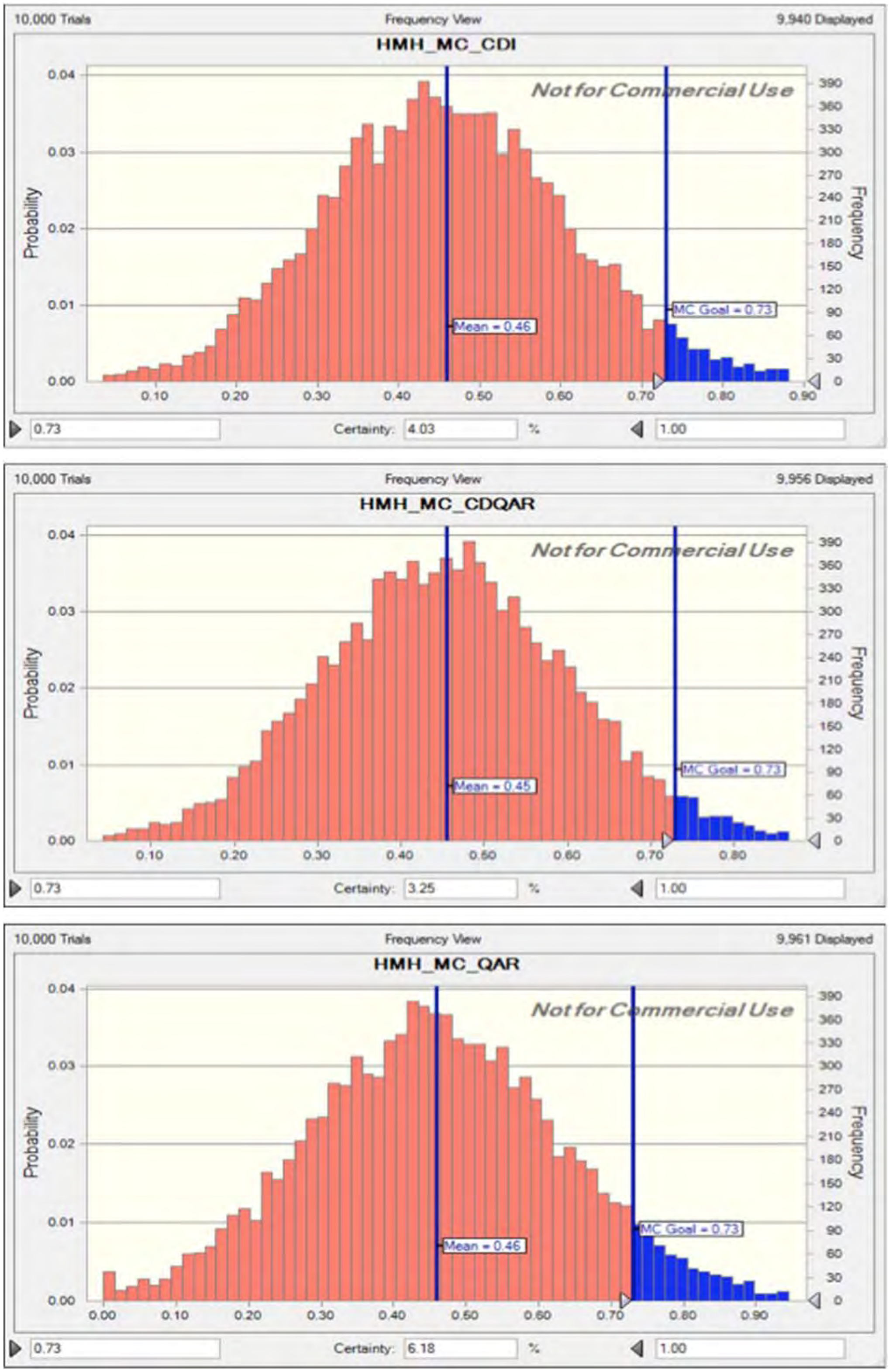


Figure 17. HMH Recommended Qualifications at Average States Simulation using Regressions Results

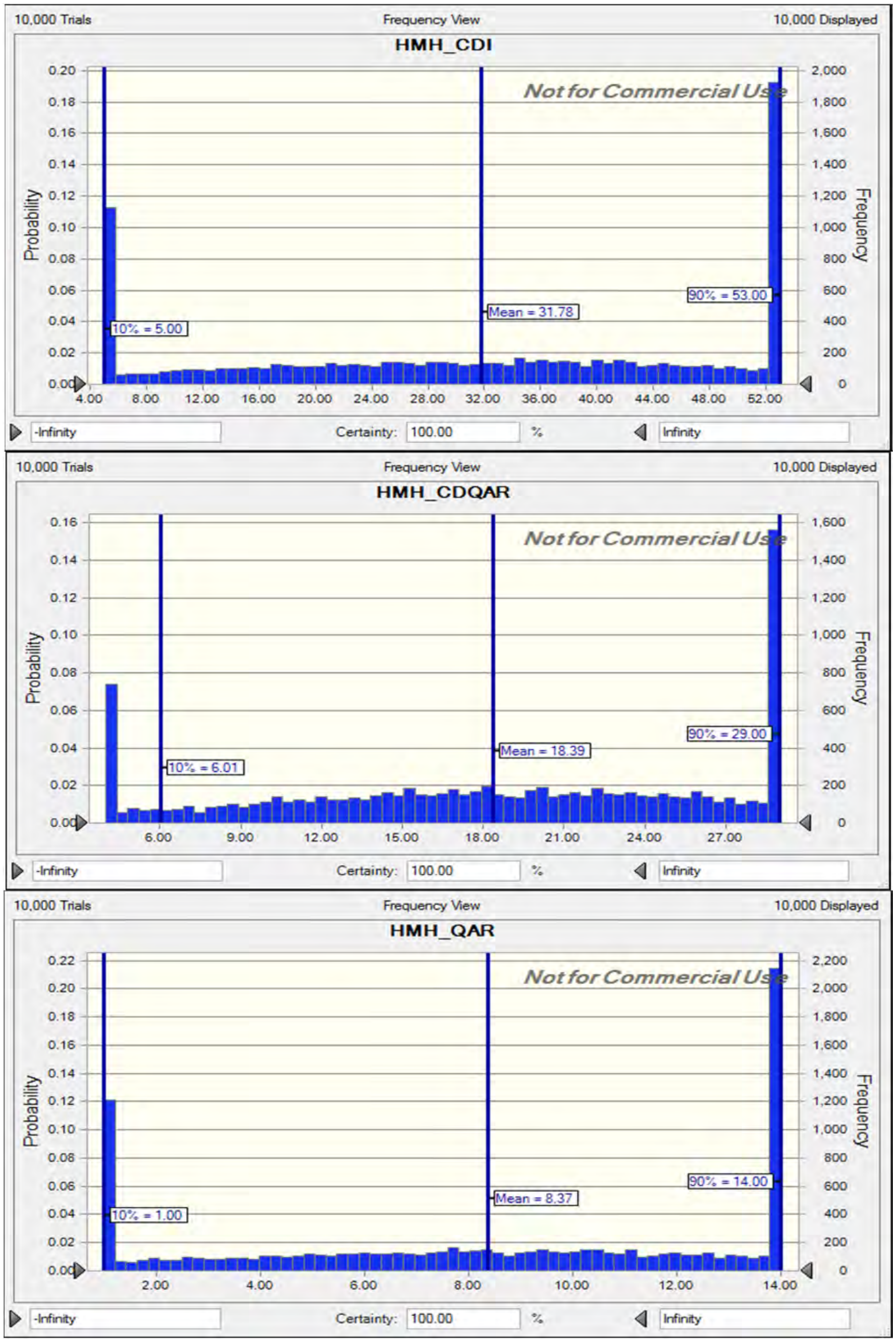


Figure 18. HMH Recommended Qualifications at 10% Higher than Average MC % Simulation using Regressions Results

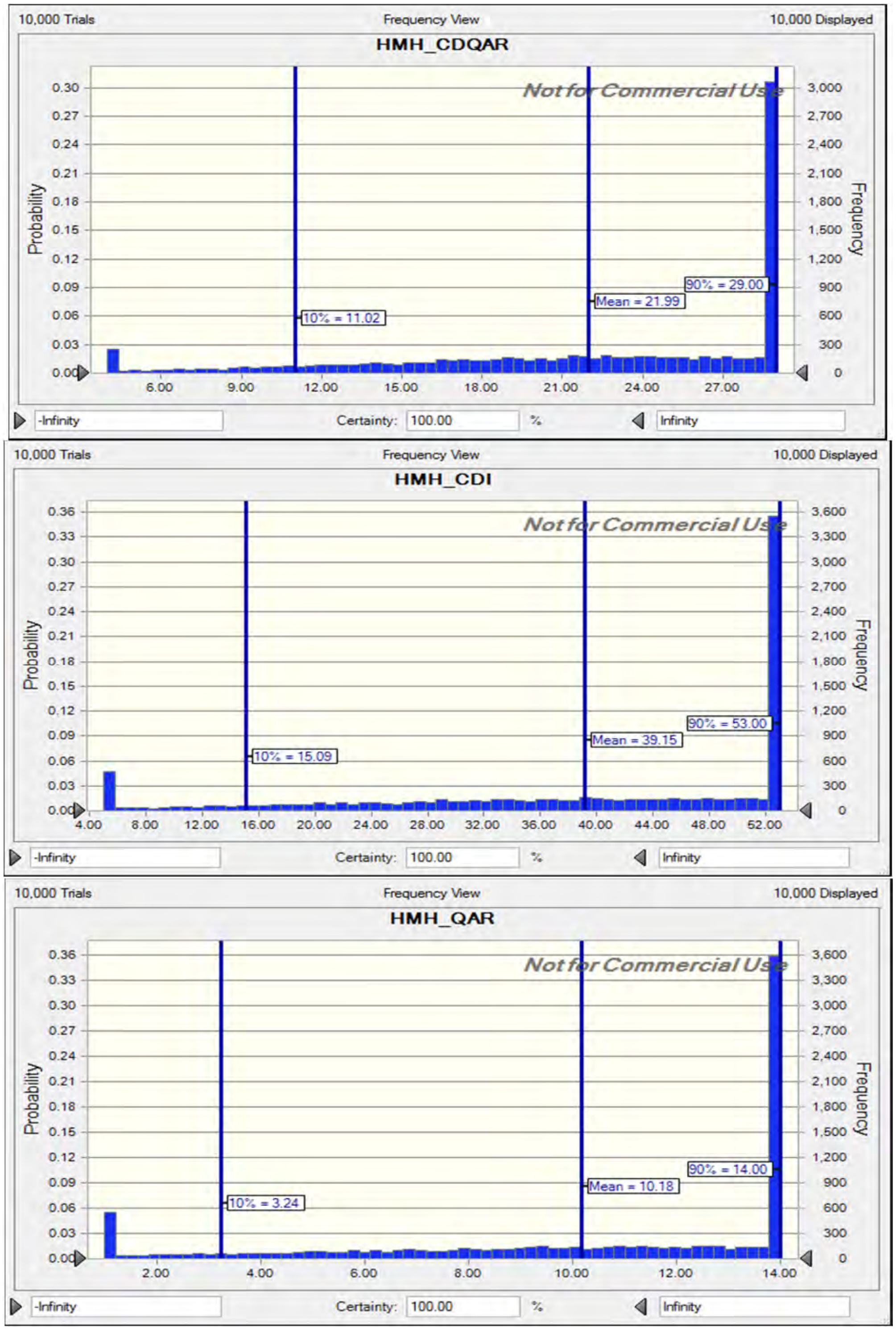


Figure 19. HMH Recommended Qualifications at Average States but with 11 Planes (vice 9) Simulation using Regressions Results

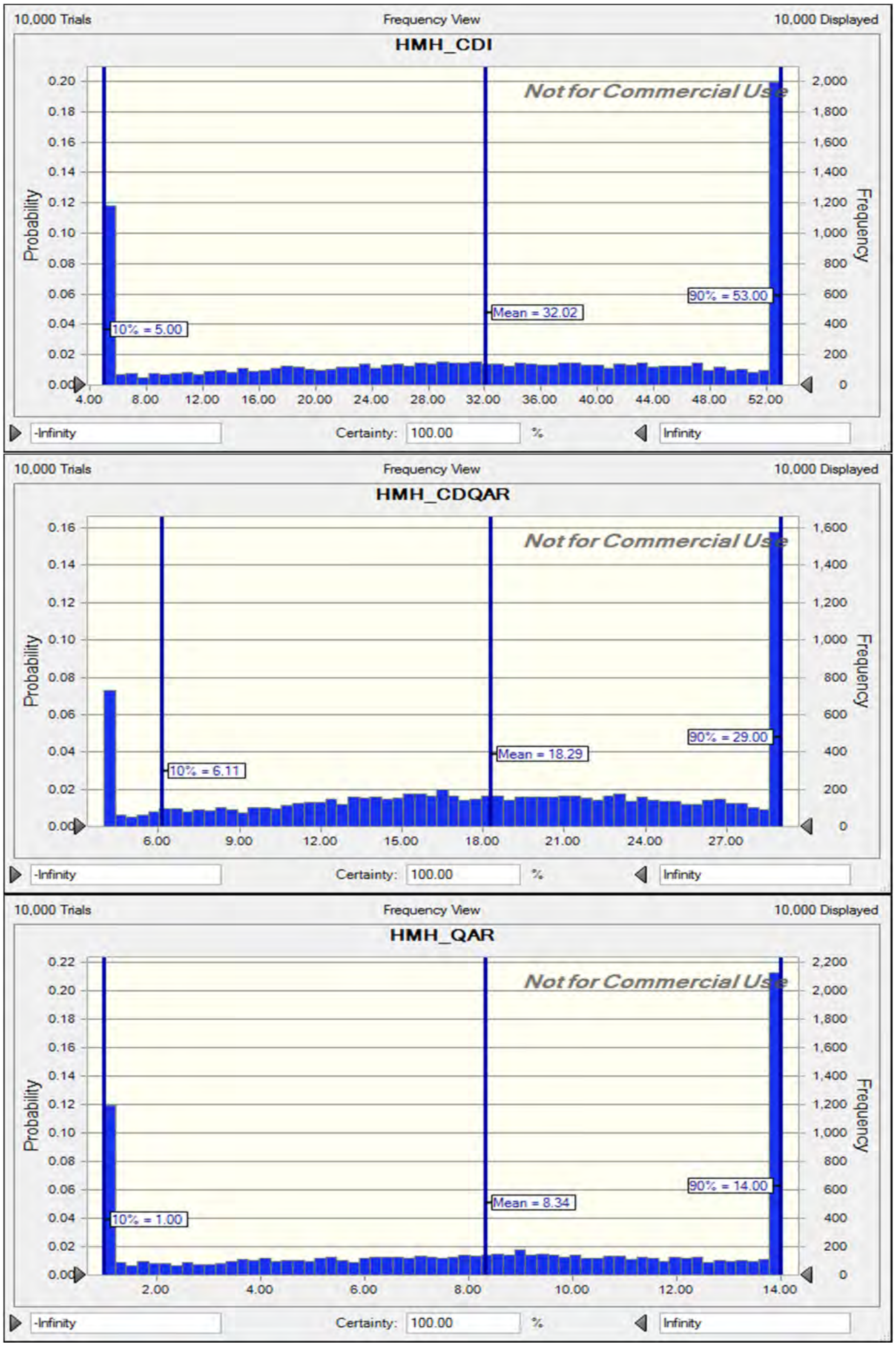


Figure 20. HMLA Underlying Distributions

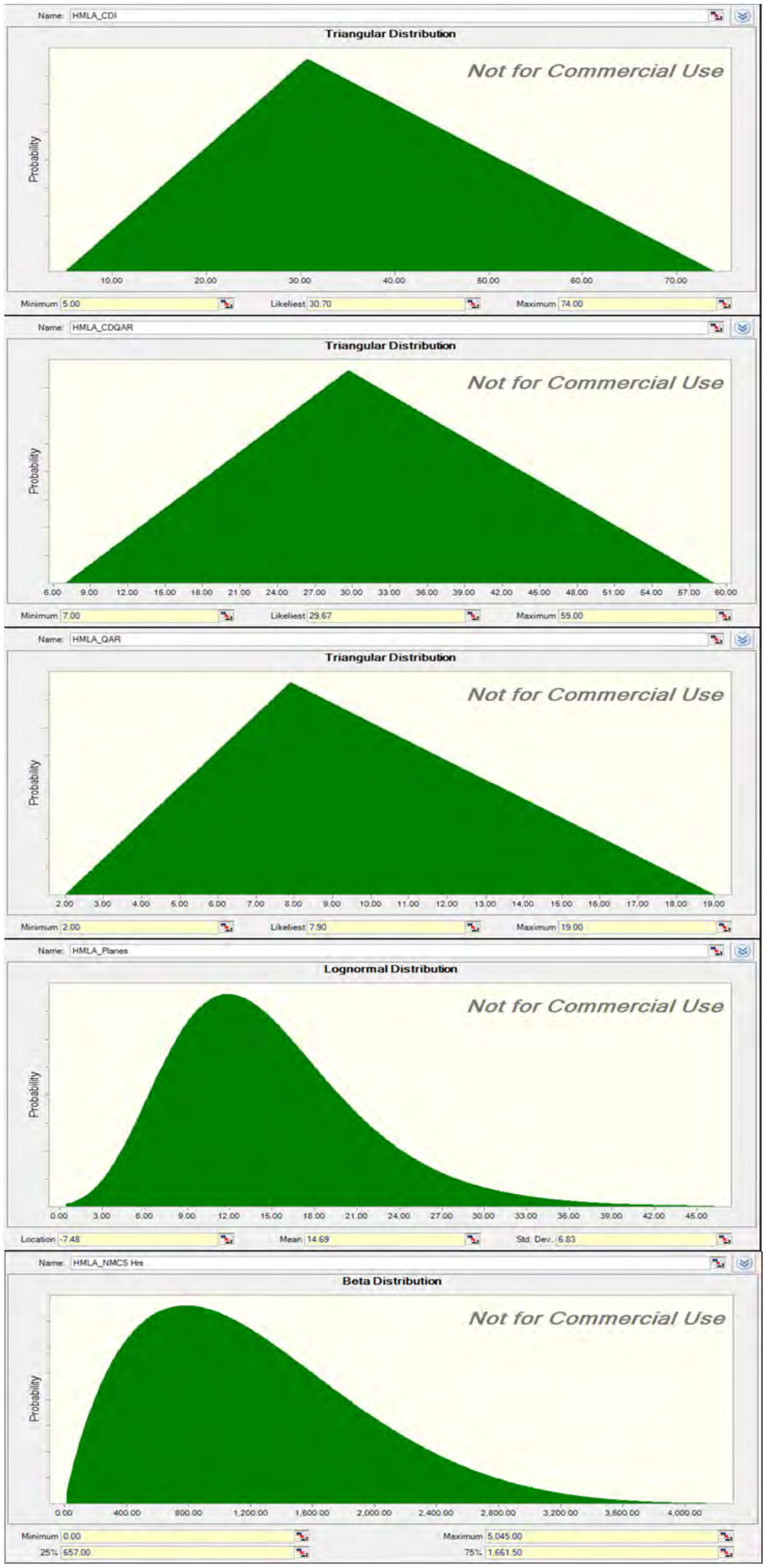


Figure 21. HMLA Regressions, MC % Simulated at Average States

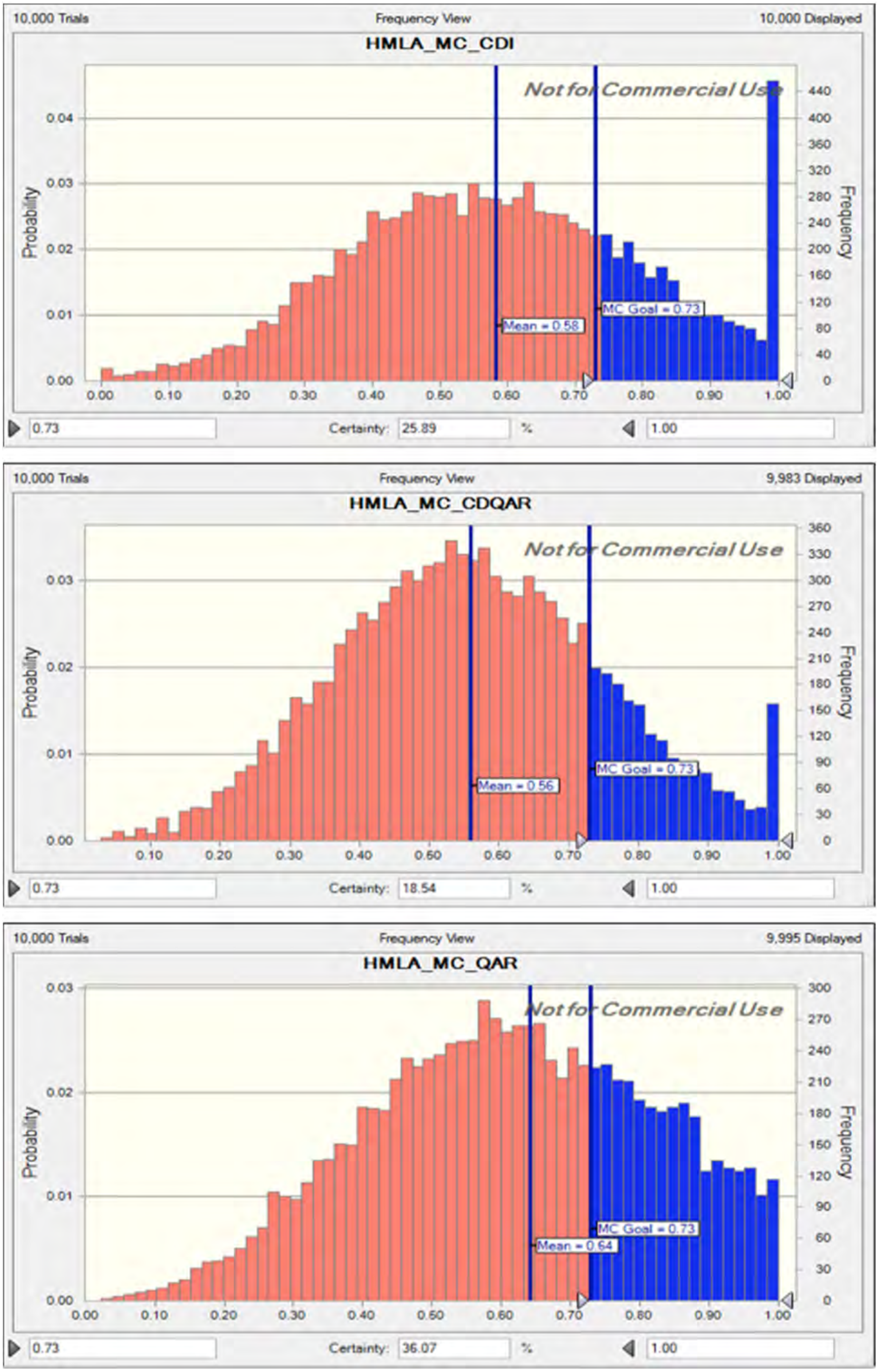


Figure 22. HMLA Recommended Qualifications at Average States Simulation using Regressions Results

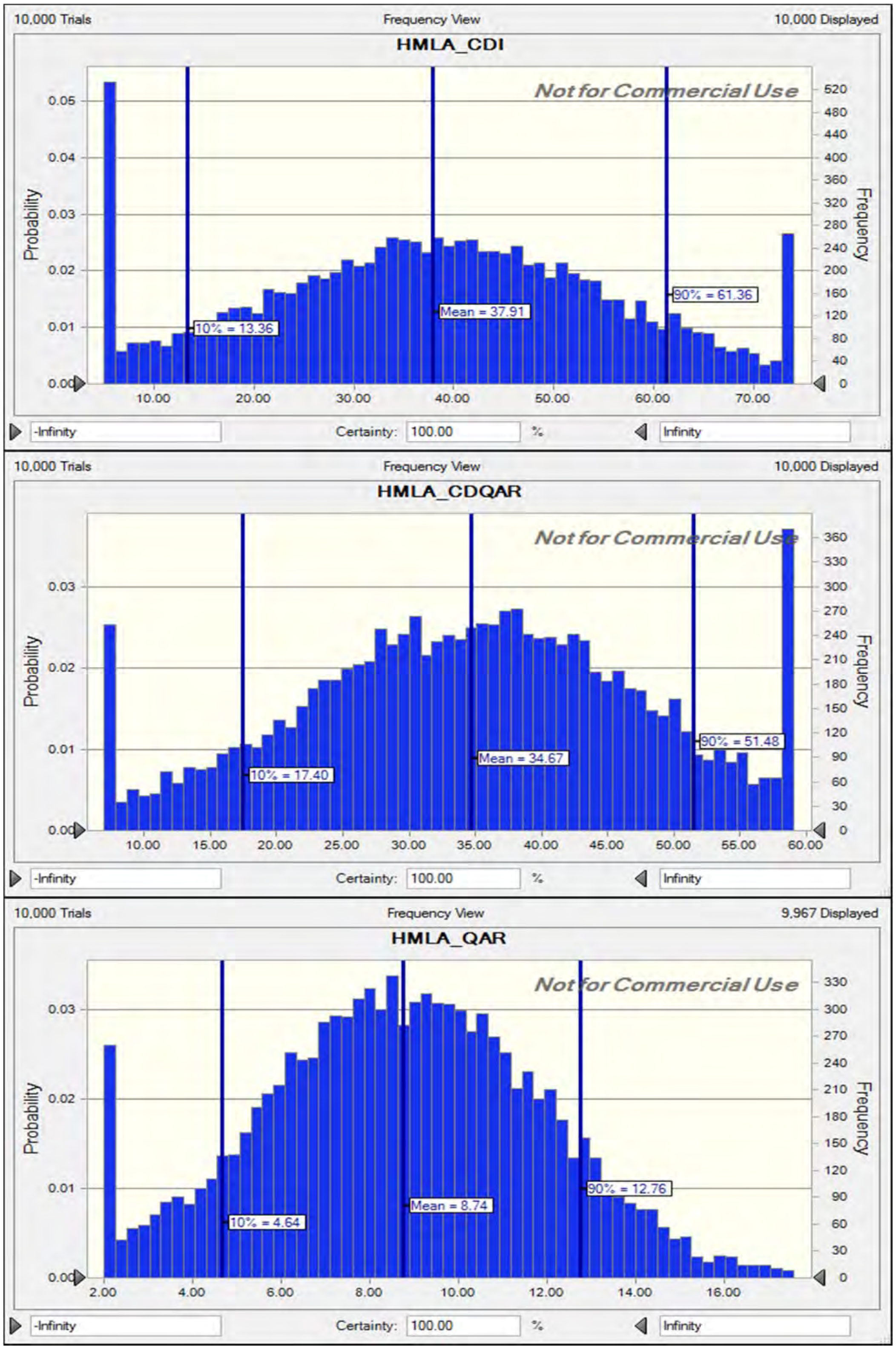


Figure 23. HMLA Recommended Qualifications at 10% Higher than Average MC % Simulation using Regressions Results

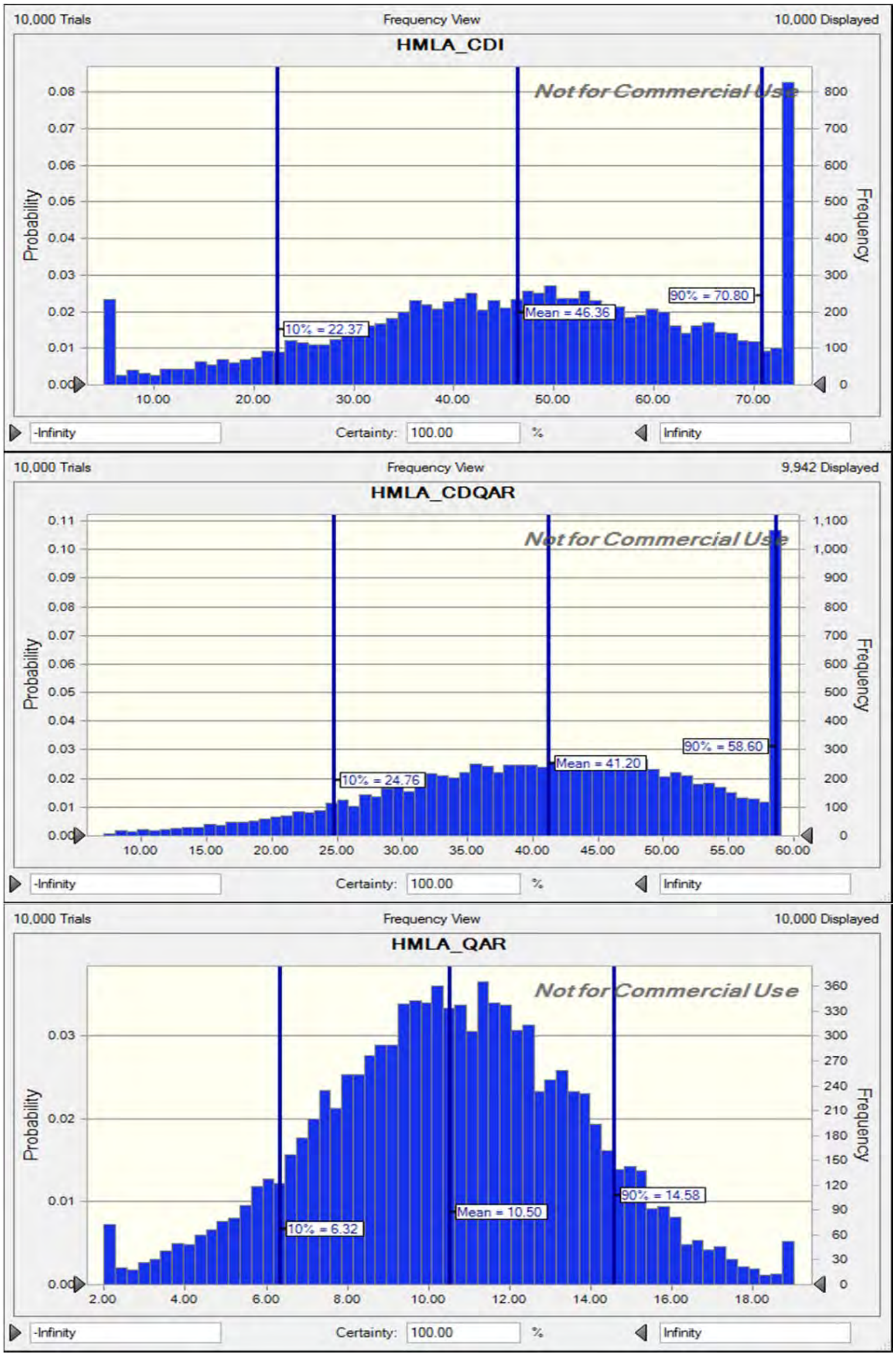


Figure 24. HMLA Recommended Qualifications at Average States but with 20 Planes (vice 15) Simulation using Regressions Results

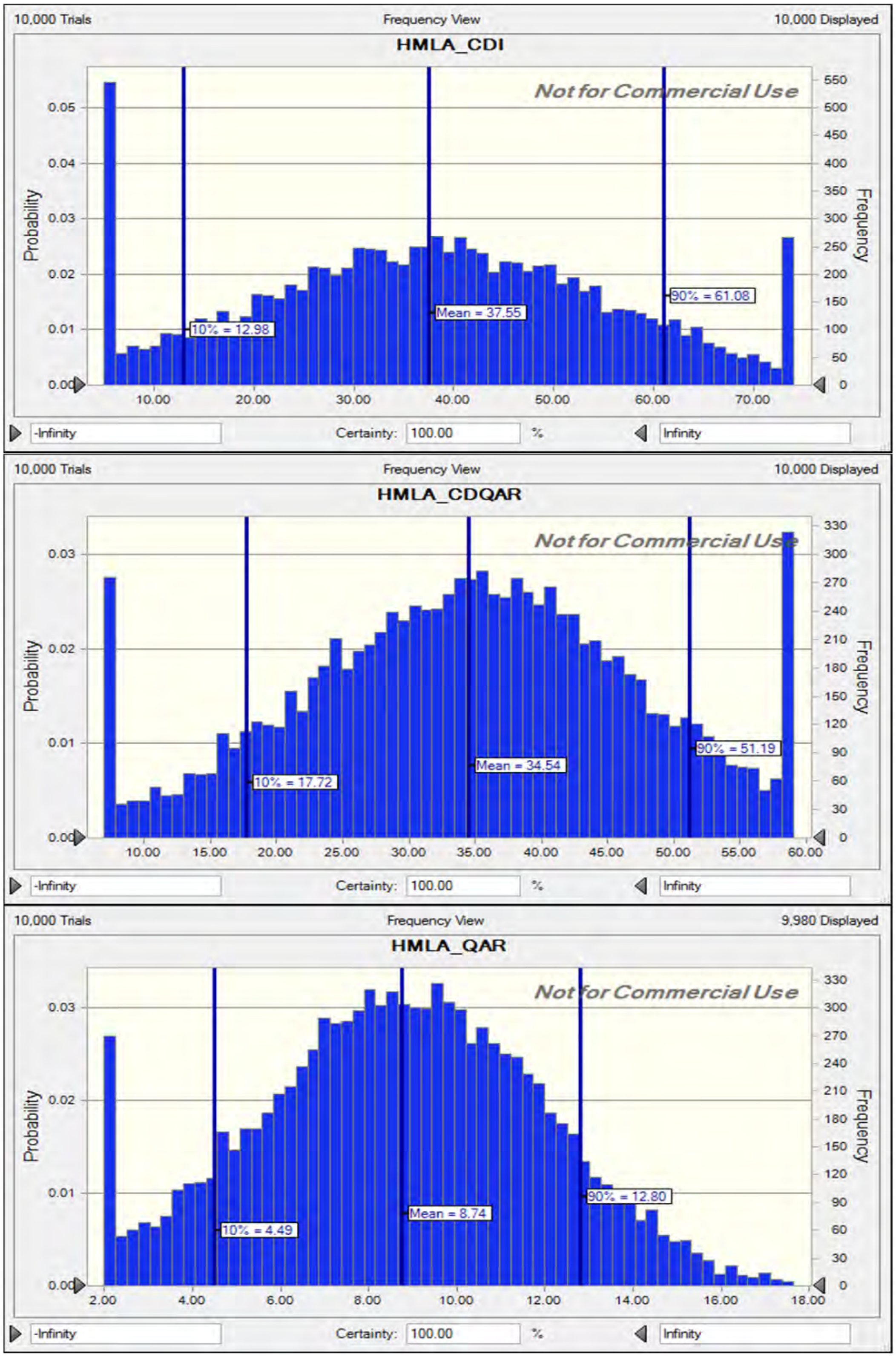


Figure 25. VMM Underlying Distributions

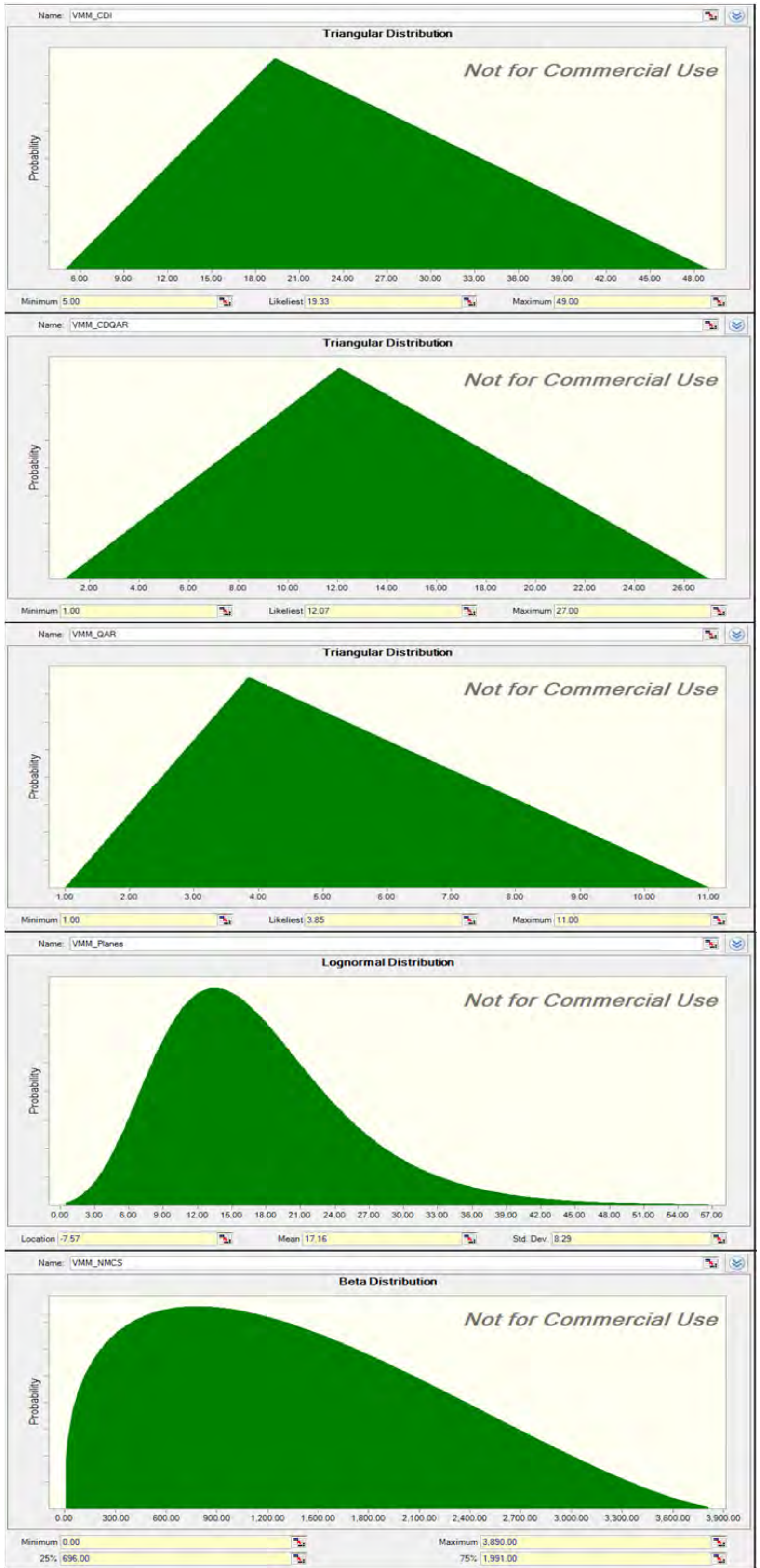
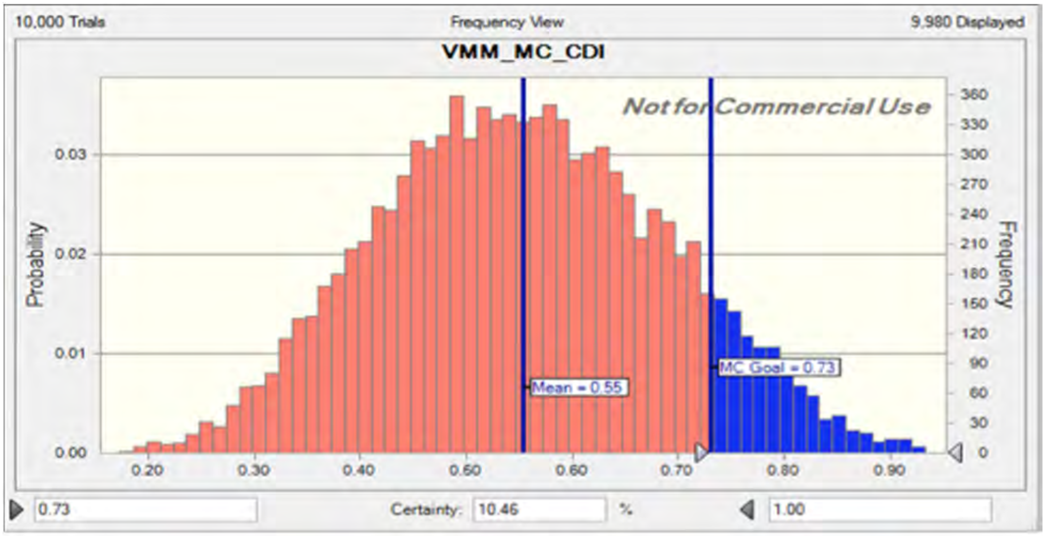
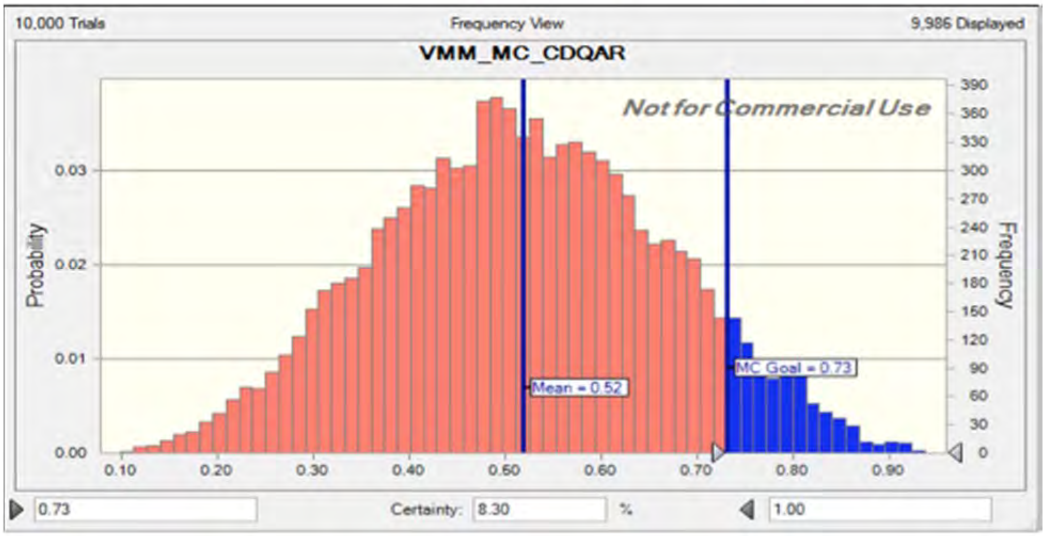


Figure 26. VMM Regressions, MC % Simulated at Average States





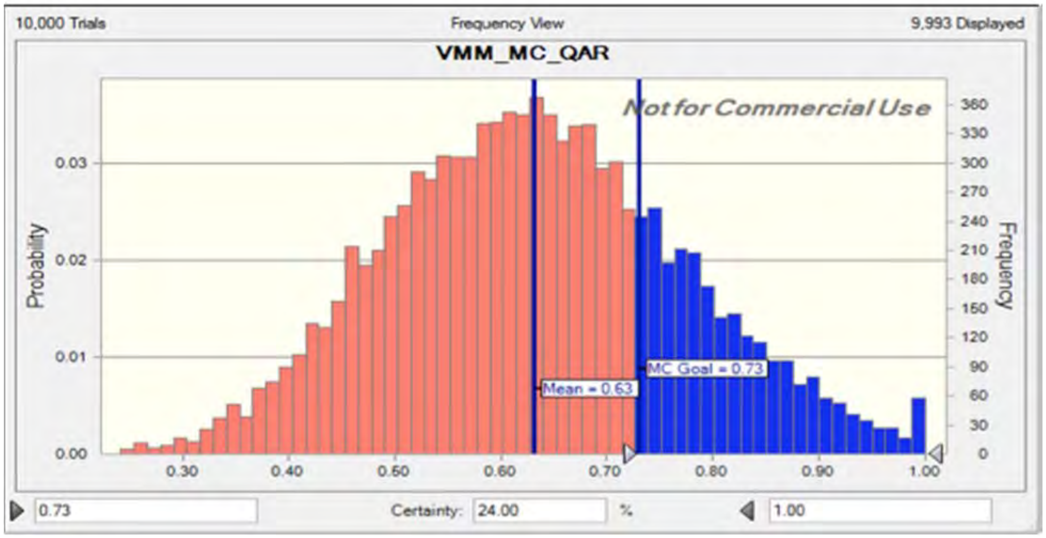


Figure 27. VMM Recommended Qualifications at Average States Simulation using Regressions Results

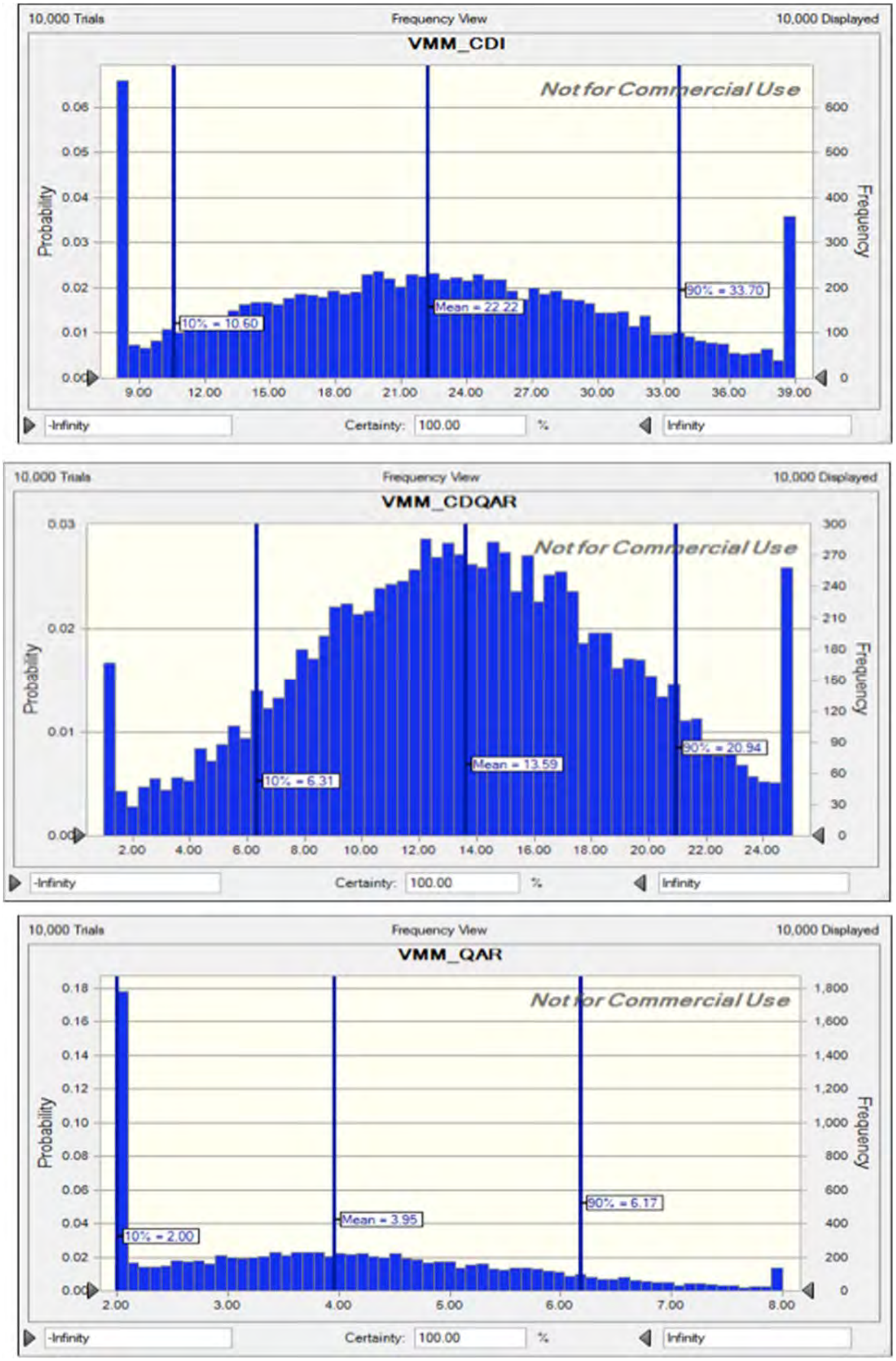


Figure 28. VMM Recommended Qualifications at 10% Higher than Average MC % Simulation using Regressions Results

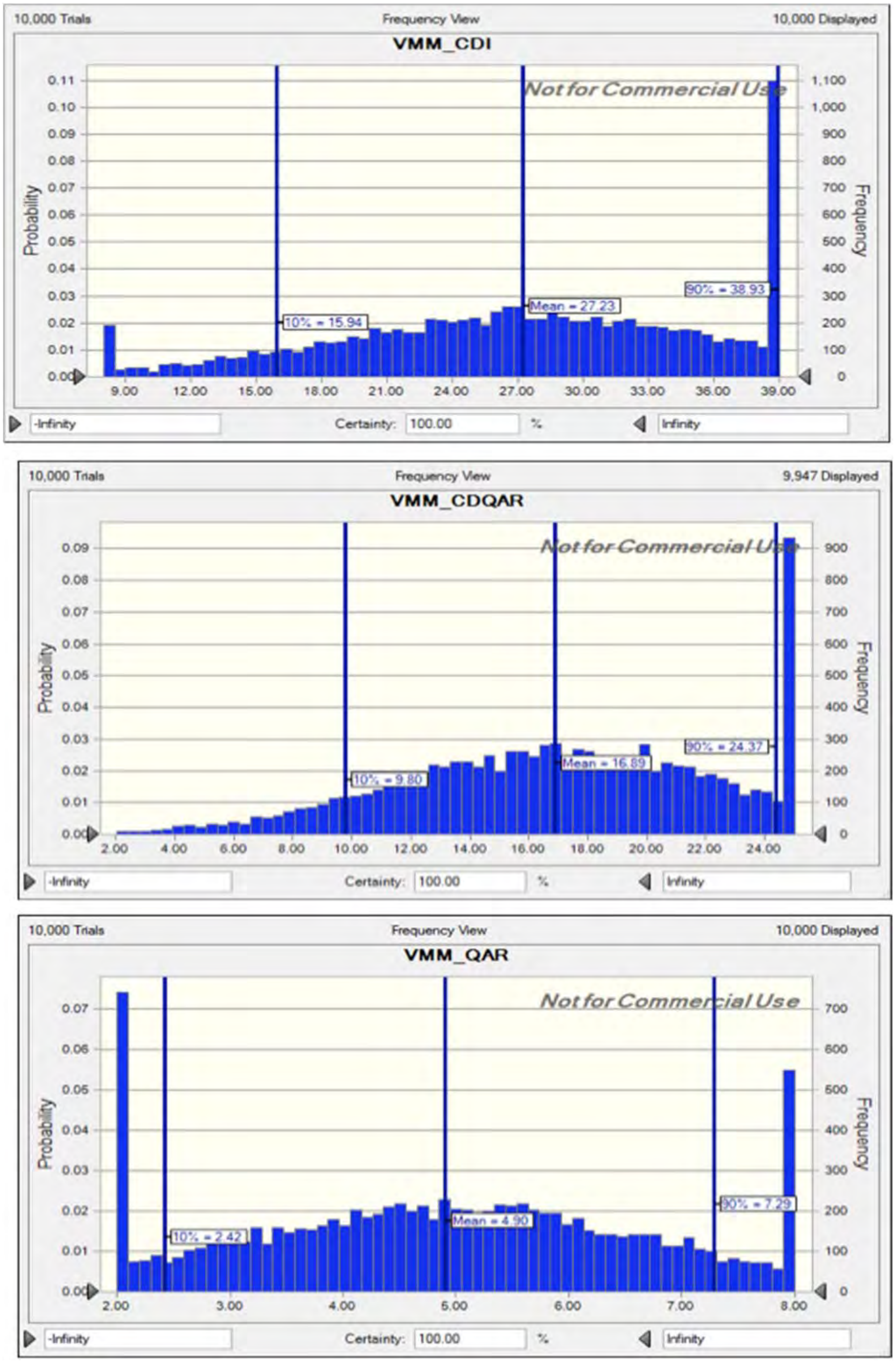


Figure 29. VMM Recommended Qualifications at Average States but with 12 Planes (vice 10) Simulation using Regressions Results

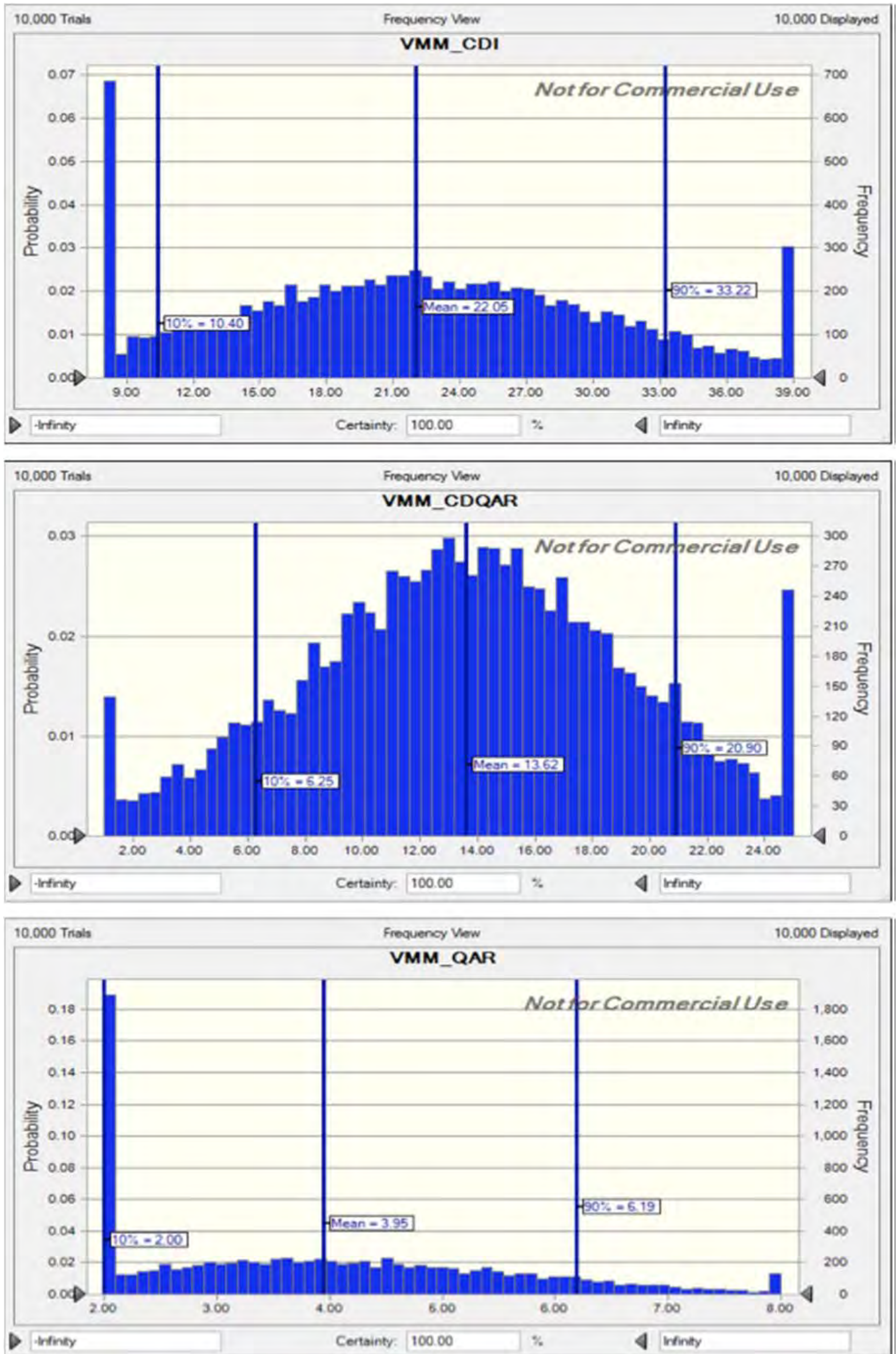


Figure 30. HMH Recommended Qualifications to meet MC Goal of 73% on Average

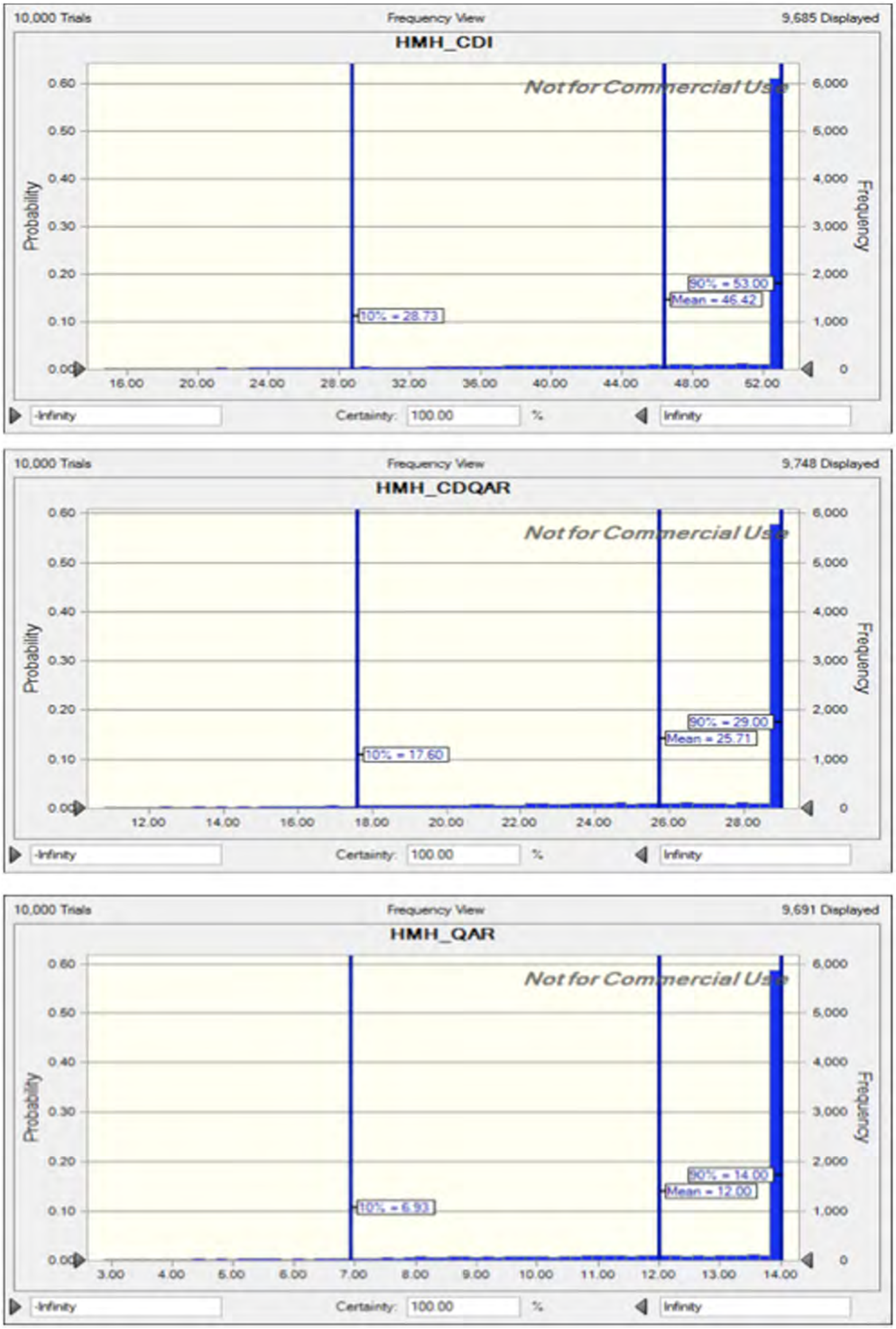


Figure 31. HMLA Recommended Qualifications to meet MC Goal of 73% on Average

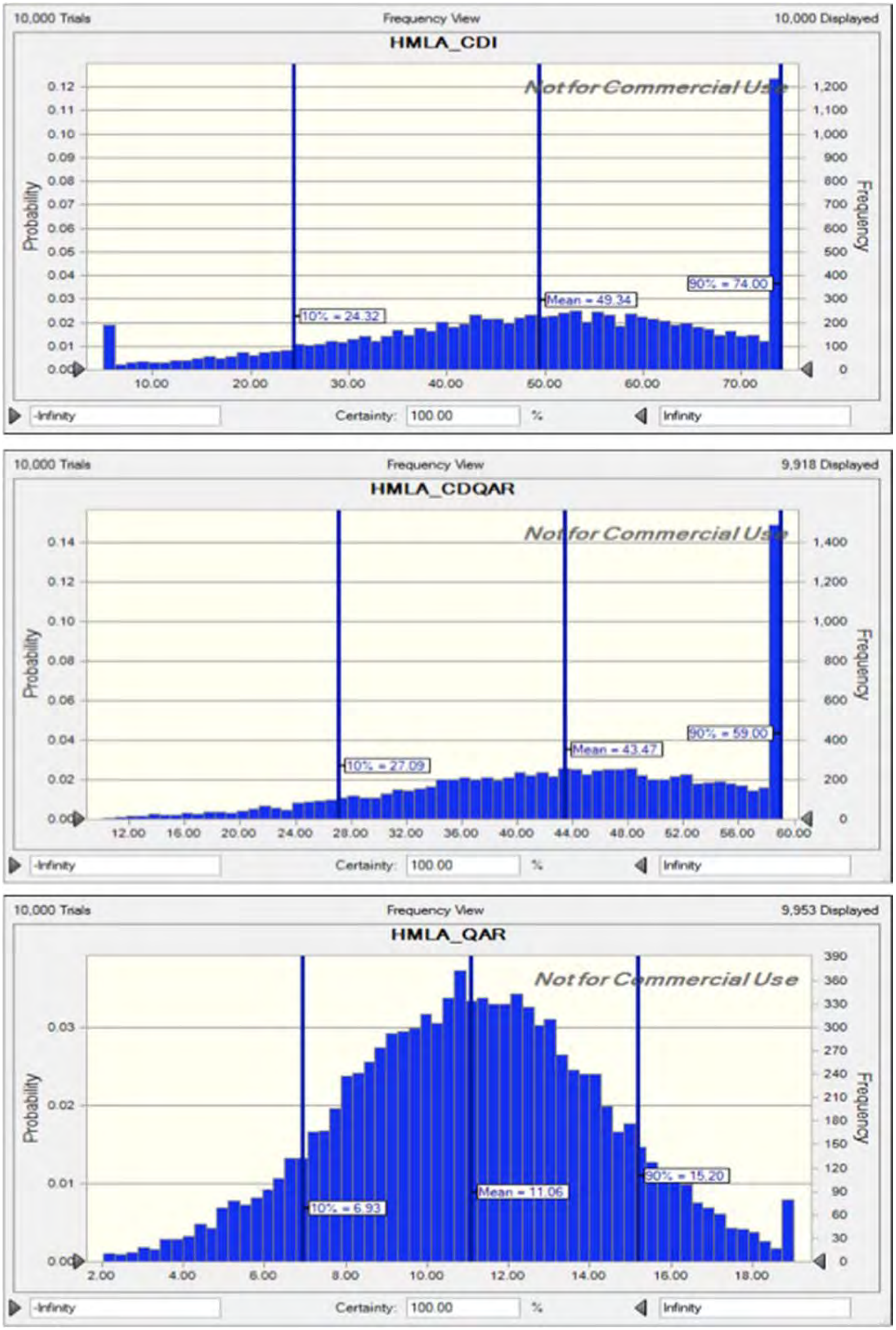
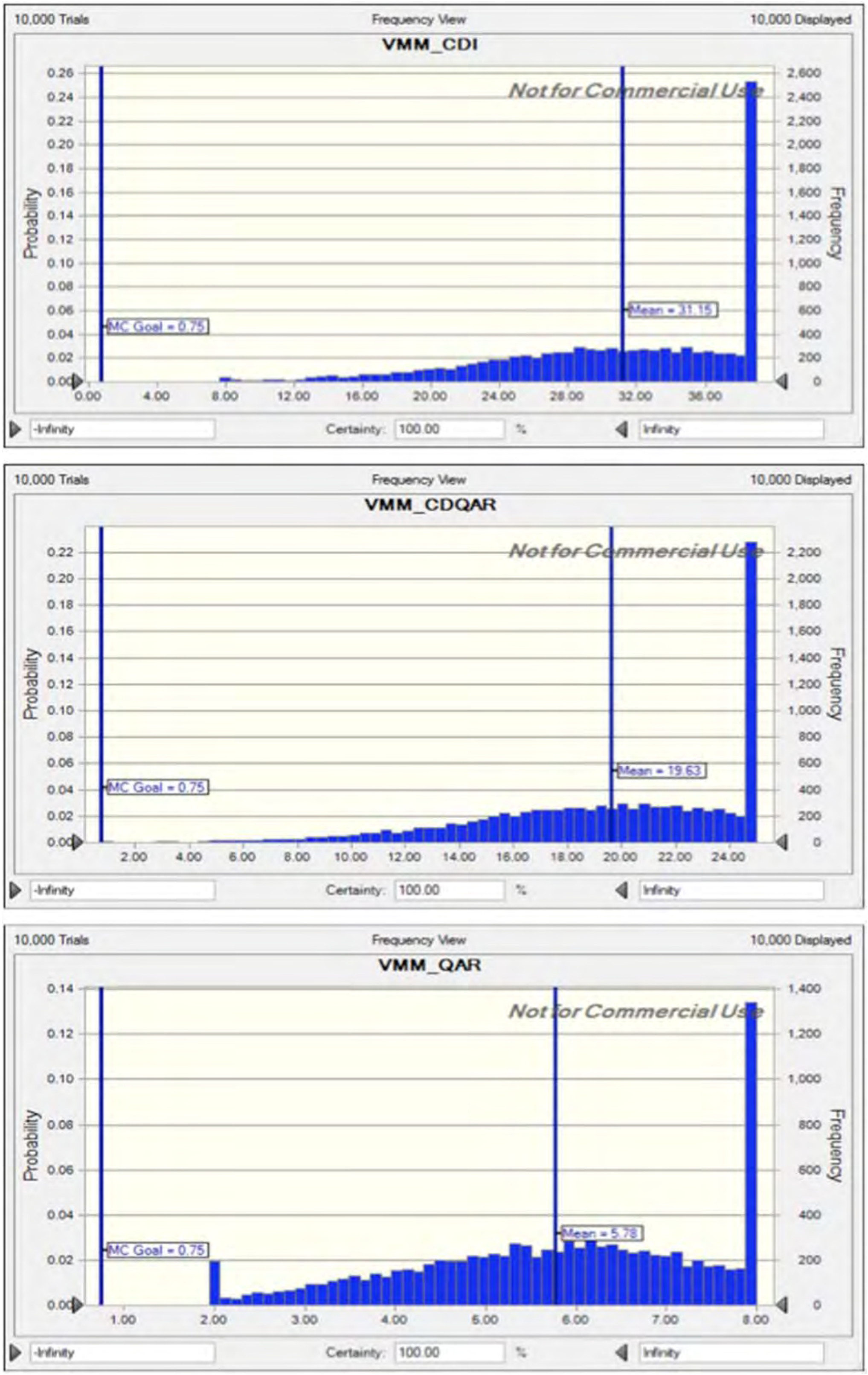


Figure 32. VMM Recommended Qualifications to meet MC Goal of 73% on Average



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